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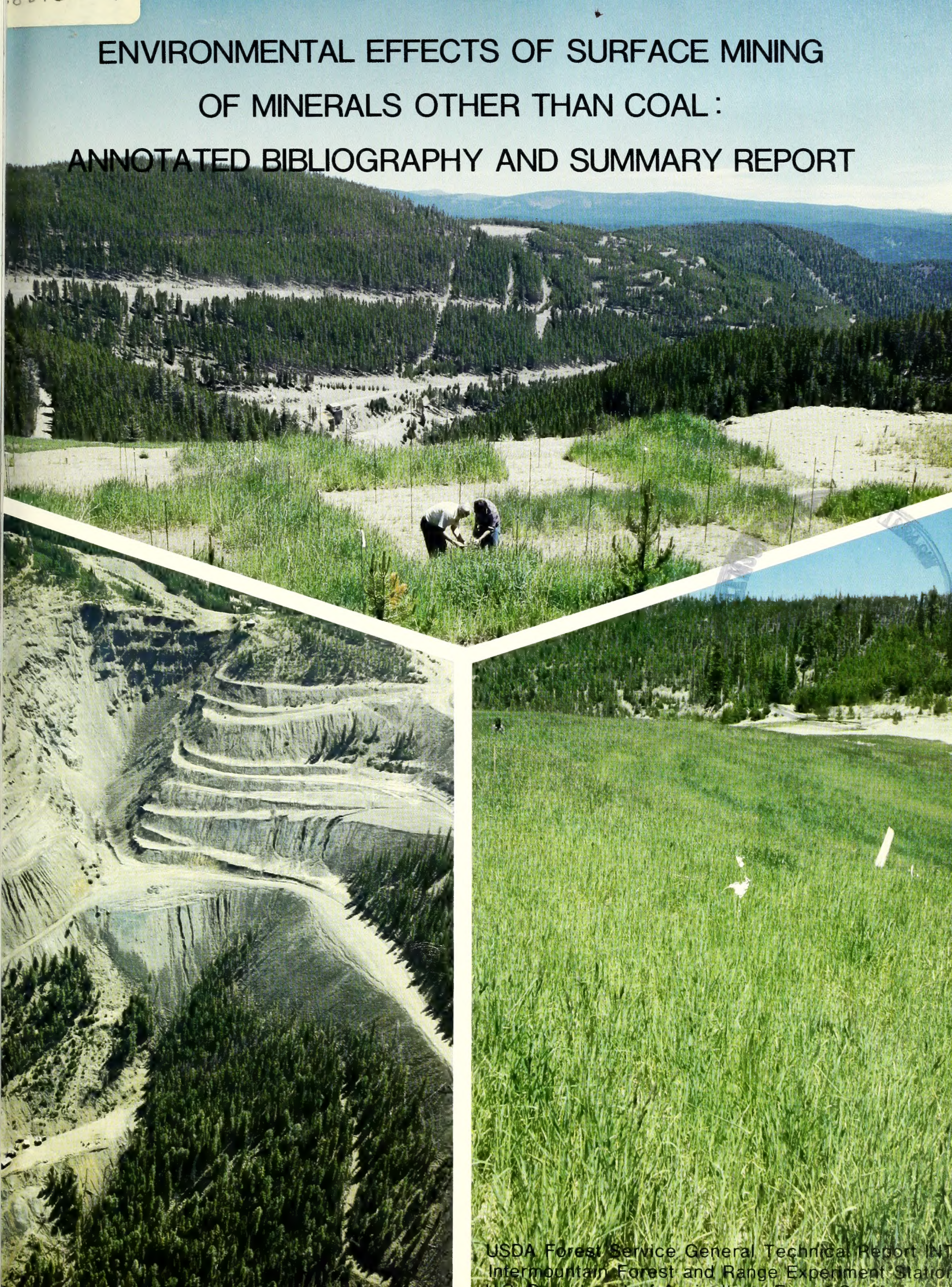
ENVIRONMENTAL EFFECTS OF SURFACE MINING OF MINERALS OTHER THAN COAL: ANNOTATED BIBLIOGRAPHY AND SUMMARY REPORT



USDA Forest Service General Technical Report INT
Intermountain Forest and Range Experiment Statio

This bibliography was compiled from various sources including computerized data bases, personal literature collections, and the results of a national survey. We have strived to achieve as much consistency and accuracy as possible.

Because we will maintain this bibliography as an active computerized file and publish supplements to it from time to time, we would appreciate your help. If you encounter incorrect citations (perhaps of your own work or that of your colleagues) or know of citations we have missed, please send this information to:

Bland Z. Richardson
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Intermountain Forest and Range
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COVER PHOTOS

Problem: A western copper cobalt open pit with waste dumps radiating in all directions. Waste dumps consist mainly of acid-forming sulfide minerals. The white areas are primarily magnesium and aluminum salts. The blue areas indicate severe phytotoxic concentration of metallic ions. Natural vegetation is predominantely lodgepole pine and subalpine fir.

Research: The squares of varying intensities of green and tan show results of vegetation research utilizing chemicals, fertilizer, mulch, and various mixtures of plant species.

Application: The best combination of treatments as determined through research is applied to waste dumps that were bare of vegetation for 20 years. White area in background is untreated. Dark green area in background is an undisturbed lodgepole pine stand. The deeper shade of green in the foreground indicates greater species density and is a reflection of treatments used in establishing vegetation. As succession progresses, grasses will give way to the natural invasion of lodgepole pine and subalpine fir.

USDA FOREST SERVICE
General Technical Report INT-95
November 1980

ENVIRONMENTAL EFFECTS OF SURFACE MINING OF MINERALS OTHER THAN COAL: ANNOTATED BIBLIOGRAPHY AND SUMMARY REPORT

Bland Z. Richardson and Marilyn Marshall Pratt, Compilers

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
U.S. Department of Agriculture
Forest Service

ACKNOWLEDGMENTS

The authors thank members of COSMAR who made useful suggestions, especially Dr. James Boyd, Chairman of the Committee; Michael McCloskey, Chairman of the Environmental Subcommittee; and Dr. Beatrice Willard, Colorado School of Mines, who contributed many valuable ideas.

Elizabeth Close, Intermountain Forest and Range Experiment Station, USDA Forest Service, deserves special thanks for her valuable assistance with the computer search.

This bibliography was prepared at the request of the Committee on Surface Mining and Reclamation (COSMAR), National Academy of Sciences, National Research Council, for use in developing the COSMAR report. The bibliography was funded by the Intermountain Forest and Range Experiment Station and the SEAM program of the USDA Forest Service.

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PREFACE

Early in the spring of 1978 the National Academy of Sciences appointed a Committee on Surface Mining and Reclamation (COSMAR) and directed it to conduct an in-depth study of the current and developing technology of mining and reclamation operations for minerals other than coal. This study was intended to provide scientific and technical assistance in developing legislative recommendations for the establishment of effective and reasonable regulation of these activities where necessary and appropriate.

The present report was originally written for COSMAR. Its purpose was to determine and evaluate, wherever possible, the state of the art of mitigating adverse environmental effects of surface mining, and to aid members of the Environmental Subcommittee of COSMAR on the significance of environmental problems.

On November 14, 1978, the authors started an extensive computer-based search of literature using the Lockheed data vendor. Keywords used were generated from a preliminary manual search and a review of a checklist of known environmental problems developed by the Environmental Subcommittee. Data bases chosen for the search were those that appeared to be most comprehensive, and those that index materials most closely associated with surface mining and with the environment and natural resources.

The Office of Arid Lands Studies at the University of Arizona provides a current alerting service (SEAMALERT) that lists current literature about reclamation of surface mines. We used this service plus several data bases through the RECON data vendor at the University of Arizona.

In order to obtain as much current research information and important "soft" (unpublished) literature as possible, we conducted a national survey by sending an inquiry letter to some 340 knowledgeable persons. This letter asked for: (1) comments based on professional experience and research on significant environmental problems related to surface mining, and (2) citations, publications, and reports on current research. The letter was sent to mining associations; to persons presently conducting research on reclamation of surface mines; to environmental concern groups; and to all States' departments or divisions that are involved in reclamation of surface mines. All responses received were read, their citations cataloged, and their comments recorded.

Citations generated by the computer search (more than 1,500) were read and cataloged according to problem studied and commodity involved. Only citations that had direct relevance to the COSMAR study were selected for this bibliography. Available abstracts are included. Abstracts usually are those written by the authors of articles or reports, but some abstracts included here were available through the abstracting service within various data bases. Publications received in response to the survey were abstracted by the authors of this report.

All citations are grouped by general problem subjects and are cross-referenced in the Environmental Effects index. The index lists environmental effects/problems in an effort to make available as much information as possible and to organize this information into a useful tool.

RESEARCH SUMMARY

This bibliography was prepared at the request of the Committee on Surface Mining and Reclamation (COSMAR), National Academy of Sciences, National Research Council, for use in developing the COSMAR report. The bibliography determines and evaluates, wherever possible, the state of the art of mitigating adverse environmental effects of surface mining for commodities other than coal. It contains results of an extensive computer-based literature search and responses to a national survey. Citations that have direct relevance to the COSMAR study were selected for the bibliography. Available abstracts are included. Each reference is indexed by commodity, general subject, and environmental problem. The publication includes a section of references to unpublished literature and a summary of professional concerns about mining impacts throughout the United States.

GUIDE TO USAGE

Section I

Section I was compiled directly from responses to the inquiry letter. Therefore, it is a summary of professional concerns about reclaiming surface mined areas throughout the United States. The comments represent years of research or direct professional experience with surface mining and reclamation.

Comments are referred to by letter and numeral and are referenced at the end of the section. For example, B5 refers to the fifth entry under "B. Effects of Climate and Geography on Mitigation Efforts." It is a quotation from A. Bjugsted of the Rocky Mountain Forest and Range Experiment Station. Presumably the author of any comment can supply pertinent technical data to support his comment. Indeed, many did this, and citations are included in Section II.

Section II

Section II contains the body of technical data in the form of an annotated bibliography. Section II-A contains citations that refer to other bibliographies and comprehensive texts that deal primarily with reclamation of surface mines. These are cited primarily to give weight to major concerns as indexed by impacts. For example, in the Index of Environmental Effects the problem of acid mine drainage has references to four citations that are bibliographies (4, 10, 49 and 60). This indicates publication of much literature dealing with the problem of acid mine drainage, and that acid mine drainage may be a significant problem.

Section II-B lists citations to reports of current research projects and current unpublished literature. Sources for this section are discussed on page 22. This "soft" literature is important because technology is now being developed that may have important effects on mitigating measures.

Sections II-C through II-N contain citations to materials in print that are grouped according to primary subject matter. Citations within each subsection are listed alphabetically by authors' surnames. The first page of each subsection describes its contents. Citations in Section II are cross-referenced in two places: (1) the Index of Environmental Effects and (2) the Summary Matrix of National Trends.

In the Index of Environmental Effects, effects are grouped by major problem subjects (e.g., air-related effects, fauna-related effects, etc.). Under major subject problems, effects are listed separately (e.g., mass emissions, fine particles, respirable dust, etc.). The index has four columns. Citations to publications that describe environmental problems are listed in column 2. Citations to articles that describe solutions or mitigating measures are listed in column 3. Citations to items that do not clearly describe a problem or a solution (e.g., bibliographies, etc.) are listed under "Other Citations." Occasionally remarks have been made to clarify meanings of the citations.

For example, the general heading "Fauna-related Effects," has a subheading "Wildlife Habitat." Citation 515 is listed as a "citation describing a problem" associated with wildlife. It is entitled "Effects of Surface Mining on the Fish and Wildlife Resources of the United States." The abstract tells us that about 2 million acres of fish and wildlife habitat are damaged by mining. Citation 510, listed as a "citation describing a solution," is entitled "A Guide for Revegetating Surface Mined Lands for Wildlife in Kentucky and West Virginia." The abstract indicates that this guidebook is an aid to land managers in revegetating surface mined land areas for wildlife. It includes information about species, planting and seeding methods, and other mitigating measures.

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SECTION I.

COMMENTS ON SIGNIFICANT ENVIRONMENTAL EFFECTS

This section summarizes professional concerns about environmental problems expressed by interested individuals throughout the United States. These comments represent years of research or direct personal experience with surface mining and reclamation. Similar comments about specific problems were made by several persons, often representing industry, research, and environmental concern groups.

Environmental problems and comments in this section were compiled directly from responses to the inquiry letter and have not been edited. Most comments received are included without regard to conflicting opinions or to the authors' personal biases. These problems were judged by the responding individual to be "significant" on the basis of his experience or research. References for each comment are listed on pages 12-14.

A. Philosophy and Goals

1. Development of criteria (or processes) for evaluating the relative long-term costs to society for the extraction of needed minerals in relation to environmental and social costs as a basis for policy decisions.

2. How to define when ecosystem stability has occurred--and translate this into criteria or operational guidelines.

3. What should be the role of natural plant succession in land rehabilitation?

4. In some cases it takes years to get approval from lead agencies involved with surface mining and reclamation ordinances to initiate reclamation.

5. Too many different local, State, and Federal agencies are involved with surface mining and reclamation ordinances.

6. The Federal government should learn from the results of the deregulation of the airlines. When governmental controls were released and free competition based on service and price were allowed to fluorish service improved and cost decreased. I hope the same principles can eventually be shown to apply to all industry and you and I as consumers will make our wills felt directly by our purchasing power rather than indirectly through Federal regulations, which in the past have proved costly (in terms of inflation) and in many cases contradictory.

7. We need the capability to evaluate mining and reclamation plans (operating plans), whatever the commodity, in the context of what is presently there, how surface protection can best be accomplished, and what can be expected as a reclaimed surface. We have found, many times, that data accumulation lists lead to excessive, expensive reports which do not always lead to better informed decisions or appropriate mitigation because these data are beyond the present capability to interpret and utilize.

8. Any list of the "most important environmental problems" associated with minerals other than coal depends upon "the eyes of the beholder," i.e., his or her personal understanding of National needs, technology, and a host of other factors.

9. The finding of a suitable end use for a land disturbed by mining, bearing in mind the possible potential adverse environmental problems resident in these sites.

10. The most important environmental problem (in Alaska) continues to be inflexible Federal regulations promulgated to solve midlatitude problems, which when applied in Alaska demand unrealistic or environmentally unsound practice. For example, certain regulations based on "best technique" in Kentucky or Wyoming, would result in intolerable environmental damage if applied in areas of permafrost. We urge that your NAS team arrange for testimony

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specific to Alaska as a part of its study of noncoal mining and reclamation practices. It is imperative that any nationally applicable laws recognize the unique environments to which they may be applied with counterproductive results. It is far easier to have necessary exceptions written into a proposal than to attempt remediation of regulations already promulgated.

11. Long-term quarries and pits have difficulty in getting a bond for commercial carriers for periods of time past 10 years.

12. In Iowa, we are aware of our problems and of the environmental problems created by the surface mines of various kinds. We are meeting those problems. When the Congress passed P.L. 95-87 and attempted to find all the problems across the Nation with all its various climatic conditions, mining techniques, kinds of overburden, etc., that put us all under the same large bureaucratic umbrella; then the problems really began.

13. Some of the problems connected with surface mining and reclamation are not technological problems at all, but nevertheless are considered serious problems in the overall context of how surface mining fits into or dovetails with the overall environmental picture or just plain wise use of the land.

14. Criteria for release of reclaimed land should be spelled out in general, practical, utilitarian terms, insofar as practical, rather than in technological, engineering type terms.

15. The state of the art (in erosion prevention, revegetation) is basically satisfactory but most of the trouble lies in finding enough adequately trained personnel and a willingness on the part of the mining companies to spend sufficient money to do the job.

16. Failure to recognize the total reclamation process and possibilities in order to reach a desirable predetermined end result.

B. Effects of Climate and Geography on Mitigation Efforts

1. How to obtain plant establishment on disturbed arid sites.

2. Violent or extra strong wind storms can be extremely devastating to revegetation or tailings.

3. In the Southwest, our principal problem in reclamation is the difficult coincidence of overburden substrates which are often saline in an area where rainfall is low, sporadic, and unpredictable.

4. In the Great Basin, mines are found at a variety of elevations and latitudes. Each site requires different solutions and there are relatively few pat answers.

5. Management of plant transpiration to promote survival of shrub and tree planting stock on bentonite and uranium spoils in northern Great Plains and/or research to determine adaptability.

6. The above problem is due to the lack of knowledge to manage the wind and temperature which promotes desiccation and/or could be used to advantage such as distribution of snow for added moisture.

7. The inability to effectively revegetate exposed mining properties (road surface, tailings dams, and spoil piles) in desert or chaparral areas due to lack of consistent rainfall and fertile soil leads to high levels of suspended solids entering receiving streams. In some cases these solids, upon settling, have covered natural stream substrates in Arizona streams as high as 0.2 m. The effect of the tailings cover is to eliminate burrowing and benthic invertebrates and to displace fish populations to less polluted areas; only migratory and adventitious species remain.

8. In north latitudes climatic constraints are of prime concern. It is necessary to determine species with adaptability for the climatic regime.

9. Alpine mine rehabilitation (general).

10. Rehabilitation of Nevada barite mines in an extremely arid environment.

11. Reclamation of arid and sodic lands. Two areas that immediately come to mind are reclamation of potential uranium mines in the Pryor Mountains where annual rainfall is as low as 6 inches, and the reclamation of bentonite areas.

12. Revegetation of tailings areas and dumps at high altitude - base metal and uranium mining.

13. Another factor which creates a potential environmental problem is an appreciable rainfall so that the operation cannot proceed without a net effluent.

14. The potential effects on the subalpine environment and identification of mitigating measures.

C. Problems of Erosion and Topography

1. Building or construction materials--this may be part esthetic but revegetation of open vertical rock faces (of ever increasing abundance) is not possible.

2. Prevention of downstream erosion of soil material. It is essential that all aspects of mining ventures be done so as to reduce soil movement into watersheds.

3. Prevention of increased surface water in downstream watersheds. Greatly increased stream flow results in soil movement and alteration of the life support system in streams and rivers.

4. Mountain hard rock mines--reclamation a problem due to mine age, lack of surface soil, and acid drainage.

5. Mass instability of mine wastes whenever they are piled on steep slopes.

6. It is completely impossible to eliminate all sedimentation and appreciably more difficult to reclaim and vegetate steep mountain sides of quarries. In many cases, the ore was bare rock with no topsoil or vegetation on it at the time we initiated ore mining activities. Our results differ very little from the state nature had developed in these instances when we started our mining operation.

7. Formation of highly turbid water in impoundments left after strip mining bentonite clay in the northern Great Plains and lack of information of specific erodibility factors for the soil and geologic conditions present that are needed to efficiently control the turbidity problem.

8. Mine spoil continually washing into streams especially during winter and spring rains.

9. High walls on the phosphate mines and how to rehabilitate them.

10. A potential problem is the high wall left by many mining operations. It is feasible, however, to eliminate the high wall upon completion of operation by setting off charges at different intervals creating a slope.

11. The effects of silt on streams which must meet the NPDES criteria for discharge.

12. Sloping of high wall--preregulated quarries which have high walls common to those high walls standing prior to the law.

13. Surface stability of the materials and overburden in temporary storage during the active mining operation and that of the recontoured site following reclamation: In this regard provision for the stable storage of large quantities of clay bearing overburden material on steep contours west of the Cascades and the stabilization of these same materials to allow revegetation of the reclaimed area constitute perhaps the major problems for the rock and aggregate mining sites in that area.

14. Management of excessive amounts of surface water which result from the rainfall which averages from 40 to as much as 200 inches of rain per year and even more in some sections of this portion of Oregon. This amount of surface water coupled with the large amounts of clay from the weathered marine basalts and the lateritic soils pose real problems in maintaining water quality in the State's stream courses in areas near any mining areas.

15. In the eastern part of Oregon the problem is equal but opposite. The arid climate and silty clay loam soils combine with periods of high wind and sudden deluges and flash floods pose unique surface stability problems both during the mining operation and for the site during reclamation.

16. High walled hardrock mines. Every quarry, including rock-borrow quarries along Vermont's system of interstate highways has been left with high walls containing loose, unscale material. These quarries are not only esthetically unpleasing but are also safety hazards for unwary rock hounds, etc.

17. High walls from clay mining.

18. Blowing tailings-base metal and uranium mining.

19. Seepage and tailing dam stabilities are environmental factors to consider in design and operations.

20. Techniques for containing the effects of erosion and sedimentation to permitted lands so that contiguous watersheds will not be adversely affected is a most important issue.

21. Exposed sides of open pit metal mines contaminate snow and water with metallic ions. This water drains through geological fractured material depositing high concentrations of metallic ions into streams.

22. Sediment discharge into stream from mining areas prior to dump stabilization.

D. Soils, Spoils, and Tailings

1. Nutrient mobility and moisture are severely restricted in spoils that are colloidal in texture and extremely high to sodium salts. Because of this condition, large areas of rangeland which have been mined for bentonite are nonproductive in terms of revegetation.

2. Any accumulation of heavy metals in the soil, particularly the copper smelter plume field and tailings pile. Arid and stress environments are most critically affected. Also heavy metals leached into stream (total impact unknown) and airborne.

3. Difficulty in establishing vegetation on mine spoils because of extreme rockiness, low pH, and toxicity of spoil material.

4. Oil shale reclamation similar to bentonite-stress environment.

5. Mine waste dumps. In Vermont great waste piles exist at the sites of our granite, marble, asbestos, and slate mines.

6. Iron and copper tailings basins also present problems. Sometimes due to acidic content, they can be inimical to life but more often they simply will not support life because of the absence of any life-promoting nutrients.

7. High on the list is the problem of the acid generating nature of sulfidic tailings.

8. The most serious problem is tailings from metal mine milling operations. The texture, chemistry, and structure of these areas are by far, in my opinion, the most serious problems in all of reclamation.

9. Kiln dust piles or agricultural lime piles. The vegetation of the kiln dust piles is difficult because the material is highly basic and contains almost no essential nutrients. The ag lime piles are product but the manufacture far exceeds the demand. As a result, large piles remain. In addition the companies do not want to stabilize these piles because they wish to sell the product.

10. Disposal of mine wastes and tailings--Montana's Hard Rock and Open Cut Mining Acts do not require backfilling and have weak provisions regarding the approximate original contour.

11. Methods of dealing with excessive amounts of molybdenum or selenium in soils either occurring naturally in association with uranium deposits, or as an aftereffect of mining.

12. Tailings stability and integrity.

13. Mass movement of material from unstable mine dumps.

14. Blowing uranium tailings.

E. Revegetation

1. Achievement of rapid revegetation of all disturbed areas. (Vegetative cover is a primary tool in the effort to prevent erosion and runoff.)

2. Inability to revegetate mine spoils because of continuous mining operations.

3. Knowledge is lacking on species (forbs and shrubs) requirement necessary for propagation and establishment on relatively inert bentonite clay and uranium spoils on the northern Great Plains. This is particularly true in regard to the needs for endo- and ectomycorrhiza.

4. Information is still lacking on site amelioration for establishment of shrubs on bentonite and uranium mine spoils on the northern Great Plains.

5. Slow process of release of plant materials to the commercial market by the agencies that have been involved in their selection and development. It seems that many varietal release committees are reluctant to put a variety of proven performers of "native" species out to commercial production as a standard.

6. The growers and collectors of the range type species that are in demand today for reclamation work cannot keep up with the quantities of seed required for the areas that are requiring treatment.

7. Inability to revegetate water impoundments left after strip mining bentonite clay in the northern Great Plains with aquatic and wet meadow species due to lack of information on appropriate techniques and species.

8. Difficulty in establishing plant stand due to inadequate moisture.

9. Establishment of normal microflora (saprophytes, nitrogen fixers, and mycorrhizal symbionts) in spoil material.

10. A major problem relates to the "availability of plant materials" that are (1) adaptable to a range of severe site conditions, and (2) are acceptable by society. Three critical site conditions in order of priority are (1) seedling desiccation (drought, low temperatures); (2) biological damage (rodents, big game); and (3) management. The problems of "socially acceptable plant materials" relate to (1) current limits of law and its interpretation, (2) realistic "planned land uses," (3) the conflicts of highly desirable native species vs. "undesirable" native species, (4) unknown responses of "introduced species."

11. Dieback problems within 3 years on revegetated, abandoned manganese and iron ore mines.

12. Revegetation and stabilization in open pit mining of base metals.

13. The overburden in certain areas contains low-grade oil sands whose relatively low bitumen content does not merit extraction. Such areas are difficult to revegetate as some components of the bitumen in these overburdens are thought to be toxic to plants in some stage

14. The tailings sand left after the oil has been extracted is extremely deficient in plant nutrients, and it is also generally poor in microbiological activity. Although the sand may be readily revegetated if amended with peat, it requires yearly fertilization to maintain a healthy plant cover.

15. Serious problems are associated with attempts to revegetate extensive acidic or otherwise toxic tailings in the absence of sufficient quantities of topsoil.

16. Bentonite clay pots (in Wyoming) become coated with glauber salt. Revegetation of these extremely high sodium areas is difficult.

17. A problem exists in establishing vegetation on alkaline soils.

18. A problem exists as to the vegetation of sediment and/or tailings ponds which are so unstable as to not allow even access by foot.

19. Revegetation of lateritic soils in Oregon poses a significant problem for the large-scale nickel mining operations as well as other proposed mining operations.

20. Fairly large-scale mining operations are either presently being conducted or are planned for diatomaceous and bentonitic materials. Only a minimum of upper horizon growth media material exists in these areas prior to mining and vegetation is sparse at best. The reclamation of these particularly sterile areas poses some unique problems which need to be addressed since these areas are subject to heavy sudden downpours, flash flooding, and strong wind erosion.

21. The rock piles of the iron mines are in some cases already 600 ft high with estimates of their reaching 1,000 ft. The individual rock fragments are from inches to feet in diameter with no overburden covering. It is impossible to provide a vegetative cover on a pile such as this, without special procedures.

22. Reclamation of hard rock mines where little, if any, salvageable soil material exists prior to mining.

23. Revegetating and stabilizing slopes containing sterile soils.

24. A problem of particularly serious importance to Colorado is plant materials suitable for revegetation above 11,000 ft. At present, about the only way to revegetate such areas back to natural conditions is saving vegetation and transplanting it. Some progress has been made in developing native seed for alpine tundra revegetation, but supplies are extremely limited and almost prohibitively expensive.

25. The determination, evaluation, and use of species with tolerant (to disturbed sites) ecotypes would substantially further the revegetation effort.

26. Utilization of a plant breeding program to make available plant lines that are adapted to the severe selection pressures on disturbed mine sites.

F. Water Pollution and Hydrological Effects

1. Solution mining and restoration of the hydrologic regime.

2. There is concern that as more mines are developed the regional hydrology may be significantly altered.

3. Tailings are frequently of such great volume as to seriously interfere with local hydrologic resources, both in terms of drainage patterns and degradation of water quality.

4. The most important environmental problems associated with copper and uranium mining and milling is the result of these metals entering streams and into the ground waters from waste dumps and tailing ponds.

5. Dewatering--the effects of dewatering quarries, pits, etc., on adjacent private and public water supplies.

6. Cyanide and stream siltation problems related to cyanide heap leaching processes.

7. Formation of fine silt ponds or lakes from the washing and refining operation of the phosphate sand, dirt, or muck. This is a very serious problem because many or most of these very fine silt or "slime" ponds or lakes will not settle or harden enough to bear the weight of cattle, machinery, etc., for many years or sometimes, apparently, indefinitely. Thus, this mining is causing a type of pollution or "waste land" at the same time that reclamation is restoring the mined-over land to useful use again.

8. Mine drainage and quarry ponds.

   a. Acid mine drainage is an environmental problem in so far as nearby surface streams are concerned.

   b. Quarry ponds are often attractive hazards in that they encourage unsupervised swimming in a hazardous environment.

9. Excess number of ponds left from sand and gravel operations.

10. Disruption of river channels from sand and gravel operations.

11. Locally, heavy metals entering surface waters. This problem may also exist relative to ground water but no definitive studies have been conducted as yet.

12. Water contamination from both tailings and mines - base metals and uranium mining.

13. Lakes created by alluvial sand and gravel operations result in large evaporative losses from the stream system.

14. Surface and ground water contamination of aquifer and stream systems is the largest environmental impact potentially resulting from noncoal mining operations.

15. Water supply and demand estimates in one of the major mining areas generally were of low quality.

16. The use of the aquifer of nearby streams for process water often lowers the water table which in turn reduces surface flow. This problem is critical in the Southwest where most streams are naturally of low volume. There are instances where water withdrawal for ore processing have essentially "dried up" streams that prior to mining activities supported abundant aquatic life (in some cases endemic fishes). This destruction of stream habitat is usually irreversible due to the low recharge rate of the aquifer. As a result, the only times of surface flow are during periods of high runoff from rains or snowmelt.

17. Consumptive water--use changing both quality and quantity.

18. Aquifer bridging by exploratory drilling.

19. A most important environmental issue concerning surface mining is the problems that arise from poorly conceived surface mining such as: pollution of soils and watersheds by chemical erosion.

20. Abandoned mine portals continually drain acid mine water, high in metal ions, into streams.

21. Dust from oxidized chalcopyrite, coballite, pyrite, and phorholite minerals collectin in snowpack is extremely harmful to all aquatic organisms.

22. There is no EPA standard for uranium in drinking water.

G. Air Quality

1. Need to develop some air quality standards that are more realistic than those currently used. The current standards have not adequately stated the basis on which they have been promulgated and have shortcomings in not adequately allowing for the fact that all environments can withstand increased levels of particulates for greater periods than allowed; the amount of particulate removal specified does not distinguish between effects of small and large particulates.

2. Particulate emissions to the environment from all types of mining.

3. Power now generated for the bitumen extraction and the upgrading process results in several hundred tons of sulfur (as SO_2) and other airborne pollutants being emitted into the atmosphere every day. Concern is being widely expressed about the eventual detrimental effect of these pollutants on wildlife, forest productivity, streams and lakes, and soils in the region, especially as more mines are developed.

4. Handling of mining operation particulates (fugitive dusts, vehicle emissions, other industrial particulates, and SO_2) in light of the 1977 Clean Air Act requirements.

5. Reclamation of some gold placer tailings both in stream and river beds and at sites of high bars may *not* result in a best use, as the disturbed channels provide ponds which enhan fish and wildlife habitat.

6. A serious problem is the contamination of local air due to the conveyance of airborne particulates due to blowing of unvegetated, active mine tailings.

7. The most significant impact that comes to mind is the presence of uranium particles in the smoke from phosphate smelters. Uranium is frequently found in minute quantities in the same formations in which phosphate ore occurs.

H. Fish and Wildlife

1. The wildlife data generally available are of low quality.

2. What makes a suitable wildlife habitat in rehabilitating disturbed lands?

3. The effects of discharges containing potentially toxic metal ions on aquatic life in streams are often hard to substantiate. Other than fish kills, the effects of heavy metals on the stream biota are not as immediate or distinct as those of settled suspended oslids. Contaminated streams continue to support aquatic life despite sporadic fish kills; however, the biological condition of these populations remains largely unknown. Evidence of metal bioaccumulation in resident species may suggest that possible detrimental effects may be manifested in the future.

4. The tailings ponds contain oil scums which are a hazard to wildlife, especially migrating waterfowl. There also is some concern that streams and rivers could be polluted with oil, heavy metals, sediments (sludges), and salts from the tailings ponds if the dikes should fail. Leaching of hydrocarbons, salts, and heavy metals from the tailings pond into the ground cover system is another area of concern.

5. The entire problem of alteration of water quality is problematic. As anadromadous fish are a prime resource to be protected in Alaska, we are very concerned over any changes in water quality, especially trace element abundance, which are apparently the homing beacons used during spawning runs. It would appear that any alteration of natural waters may be damaging: whether by introduction of "pollutants" or by "cleaning up," through neutralization or clarification regulations. However, the limits and impacts are poorly known, especially for the changes made by "cleaning up" waters in a naturally acidophyllic palludal environment. We hope to be able to arrange for such a study in the near future.

6. Sand and gravel or placer operations located near spawning areas are of particular concern.

7. Lakes created by alluvial sand and gravel operations are generally good for waterfowl and aquatic species.

8. Habitat destruction occurs through stream rechannelization and altered flood drainage caused by some sand and gravel operations.

9. Need to identify the actual effect of minerals development on threatened and endangered species and other wildlife.

10. The methods in which mining takes place in some areas resulting in highways have caused a significant delay in elk and deer reaching their winter ranges.

11. Mining activity often causes adverse impacts on wildlife other than big game due to increase in activity, access, and numbers of people in the back country.

12. Mining often results in destruction of *mature* wildlife habitat which even the best reclamation efforts cannot replace.

13. Often, reclamation efforts are not designed to benefit wildlife habitat.

14. The surface mining of oil shale and the subsequent impact on wildlife are of major concern.

I. Abandoned Mines

1. Rehabilitation of abandoned placer operations.

2. Abandoned small mine rehabilitation.

3. Blowing mill tailings from abandoned (copper) mines are an irritant to nearby settlements and a source of toxic metals entering streams.

4. Revegetation of old clay spoil dumps where topsoil is sparse. This is a very difficu problem. Without use of adequate topsoil (sometimes very hard to obtain) successful revegetation of old "orphan" (mined before the law) mine dumps has proved most difficult. Additiona research is needed here.

5. Acid mine drainage and heavy metal problems from abandoned mines.

6. We feel that since the implementation of the Act we can maintain enough control over the active sites to prevent future environmental problems. However, the abandoned operations present several problems. The sand/gravel pits often have considerable erosion. There is little nutrient or organic content of the base material.

7. Most adverse environmental effects from mining areas are usually attributable to the abandoned mines for which no public funds are available for their solution.

8. Abandoned copper mine tailings. Vermont's copper mining ceased in 1955 and large tailings dumps are still sterile deserts 24 years later. Leaching causes pollution of both surface and ground waters in the area.

9. Stone quarries present a problem. In almost all abandoned quarries there is no hope of revegetation. Also, many old quarries were left with vertical high walls, thus presenting a safety hazard.

10. Seepage from abandoned pits of low pH water into local streams.

11. Dormant uranium mill tailings piles which are not stabilized according to the stringen specifications which apply to active mine and mill sites. Surface water, ground water, and air contamination result.

J. Research Problems and Needs

1. Problems in research methodology such as: subsequent rapidly inflating prices, particularly for energy, made results of some analyses unrealistic.

2. Research needed before we can assure success of revegetation on metal mine reclamation sites in Great Basin.

3. The following is a list of high priority needed studies:

   a. Methods to predict potential ground water pollution from mining operations.

   b. Methods to protect the ground water from seepage from tailings disposal areas.

   c. Methods to control erosion and sediment discharges from all types of mining.

   d. Environmentally safe methods of solid waste handling and disposal.

   e. Reclamation of mining waste under adverse conditions, e.g., arid conditions, and high altitude.

   f. Dust and noise control for mines near population centers, e.g., sand and gravel.

   g. Thickness of earth cover over toxic materials to prevent surface and ground water pollution and promote vegetation.

   h. Maximize recycle and reuse of water in mining operations.

   i. Methods to "close down" underground mines so that they do not create environmental problems at a later date.

   j. Methods to control pollution from the inactive underground mines.

4. In both Montana and Wyoming, there are considerable bentonite orphan spoils. Because Federal funds are now available for reclamation expenditures concerning these lands, it is unfortunate that only little effective research has been done to make feasible use of the available funding.

5. The disposition of radioactive or hazardous metal mine tailings, mill processing by-products, and low grade ore needs to receive much study. We have had a history of uranium mining and milling in Oregon and at the present time there is a potential for further large scale mining operations in southeastern Oregon involving both radioactive materials and mercury ore.

6. Studies on various plant species adaptability on surface mine spoils and waste piles.

7. Establishment of microbial populations in mine spoils and waste piles.

8. Performance of individual species in various grass mixtures growing on mine overburden piles.

9. Studies in heavy metals uptake by various plants and its effects on livestock and wildlife.

10. Vertical mulching as a treatment for improving infiltration in bentonite and high clay soils.

K. Other Effects

1. Blasting - the effects of blasting on water supplies and adjacent structures.

2. Mining roads - for many hard rock mines (in Montana) the acreage disturbed by road construction approaches or exceeds that disturbed by the mine and associated facilities. Furthermore, mine roads, despite existing reclamation requirements, continue to be used by hunters, recreationists, and others upon abandonment.

3. Hit-and-run sand and gravel operators who extract gravel for a few days without a permit and then move on.

4. Radiation confinement in the uranium mining industry.

5. Hydrologic and esthetic problems associated with access and haul roads in mountains and other scenic areas.

6. Random emissions from stabilized uranium mine tailings and from reclaimed mines.

7. The social effects on small communities.

8. The economic effects of development vs. nondevelopment on local, regional, and national bases.

9. Large areas disturbed by mining exploration where suitable reclamation methods are not applied immediately after disturbance. This includes all types of minerals especially in high altitudes.

10. Potential toxic plants growing on mine spoils and waste piles.

11. Potential hazards of low-level radiation are underestimated.

12. Plants growing on uranium tailings can take up radon.

13. There exists a potential of selenium poisoning through aquifer contamination by drilling.

14. There exist health hazards associated with uranium mining (i.e., lung cancer).

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B5, B6, E3, E4	A. Bjugsted, USDA Forest Service, Rocky Mt. For. and Range Exp. Stn.
E5, E6	R. Brammer, Randall and Blake, Inc.
G7	E. R. Burroughs, Jr., USDA Forest Service, Intermt. For. and Range Exp. Stn.
B12, C17, C18, F9, F10, F12, J3	B. Campbell, Dep. Nat. Resour., Colorado
D7, E8, E23, F11	B. L. Cole, Comm. of Public Lands, Washington
B13, C19, D7	R. L. Coleman, Noranda Mines Ltd.
C8, E11	J. F. Corliss, USDA Forest Service, Region 8
C20	S. Darby, Dep. Nat. Resour., Georgia
A16, B10, C5, E4, E18, J5	G. Davis, SEAM Program, USDA Forest Service
C1, C4, D2, D4	L. E. Eddleman, Univ. Montana
C2, C3, D3, E1, E2	R. B. Ferguson, USDA Forest Service, Intermt. For. and Range Exp. Stn.
F15, H1, J1	J. R. Gray, New Mexico State
A10, F4	R. L. Harris, USDA Forest Service, Region 3
C7, E7	C. L. Hawkes, USDA Forest Service, Rocky Mt. For. and Range Exp. Stn.
B11, D10, E22, F6, I5, K2	B. Hayden, Dep. of State Lands, Montana
E24	M. Heifner, Dep. Nat. Resour., Colorado
J3	R. Hill, U.S. Environmental Protection Agency
J4	R. Hodder, Montana State Univ.
D8, G5, I3	C. M. Hofferber, USDA Forest Service, Region 6
D8, F13, H6, H7, H8, I11	D. Holm, Dep. Nat. Resour., Colorado

G1	W. A. Hunt, Mont. State Univ.
A8	J. E. Jinks, U.S. Dep. Environ., Bureau of Mines
B9, B10, C9, D7, G4, I1, I2	W. L. Johnson, USDA Forest Service, Region 4
E12, F1, G2, J4	F. T. Klinge, Ford Bacon & Davis, Inc.
B14, H9, K7, K8	B. C. LaMoure, USDA Forest Service, Region 1
E8, E9	D. Lindsey, New Mexico State Univ.
C10, E17, E18	O. W. Lineberg, Div. of Mined Land Reclam., Virginia
B7, F16, H3	M. A. Lewis, Proctor and Gamble Co.
K6	Wm. A. Lochstet, Penn State Univ.
A13, A14, A15, F7, I4	C. C. McCall, Dep. of Conserv., Tennessee
A1, A2, A3, B1, H2	C. M. McKell, Inst. for Land Rehab.
H10, H11, H12, H13	A. Mehroff, U.S. Fish and Wildlife Serv., Boise, Idaho
B8	W. W. Mitchell, Univ. Alaska
E15, F3	R. T. Moore, ERT Ecological Consult., Inc.
I10	G. Newsom, Dep. Pollution Control and Ecology, Arkansas
D11	V. H. Newsom, Surface Mining and Reclam., Texas
F19, H14	S. J. Packer-Moore, Sierra Club
F14, G6	P. S. O'Boyle, Eng. Geologist, Colorado
I7	W. Padgett, Dep. of Mines, Oklahoma
A9, D7	T. H. Peters, Inco Metals Co.
B3	L. D. Potter, Univ. New Mexico
E25, E26	P. Pratt, Range Dep., Utah State Univ.
C16, D5, F8, I8	C. A. Ratte, State Geologist, Vermont
C21, F20, F21, J6, J7, J8, J9, J10, C22, D13	B. Z. Richardson, USDA Forest Service, Intermt. For. and Range Exp. Stn.
A4, A5	D. Reining, Calif. Rock Products Assoc.
D6, D9, E21	R. Reszka, Dep. Nat. Resour., Michigan
C6	C. P. Rogers, Jr., The Feldspar Corp.
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A12	M. B. Ross, Mines and Mineral Div., Iowa
A7	R. L. Sanks, Dep. Civil Eng., Montana State Univ.
H5	R. B. Sanders, Dep. Nat. Resour., Alaska
A7	T. E. Schessler, USDA Forest Service, Region 2
I6, I9	T. Schmidt, Dep. Nat. Resour., Maryland
E10	S. Stranathan, Upper Colorado Environmental Plant Center
E13, E14, F2, G3, H4	S. K. Takyi, Alberta Energy and Nat. Resour.
A11, C11, C12, F5, K1	D. R. Thompson, Dep. Environ. Resour., Pennsylvania
B2, B4, J2	P. T. Tueller, Univ. Nevada
D1	T. Yamamoto, USDA Forest Service, Rocky Mt. For. and Range Exp. Stn.

SECTION II. BIBLIOGRAPHY

A. Bibliographies and Comprehensive Texts

Citations included in section A are those bibliographies dealing primarily with surface mine reclamation, potential solutions to surface mining impacts, and texts dealing with the same subjects. It is not possible to abstract such a section, but most of the important citations from the bibliographies appear elsewhere in this document. They are cited primarily to give weight to major concerns and are referenced by impacts in the index.

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1978. Selected annotated bibliography on the central Florida phosphate industry. 40 p. U.S. Environ. Protec. Agency, Reg. IV, Atlanta, Ga.

85. U.S. Environmental Protection Agency.
1973. A preliminary bibliography of publications concerning rehabilitation of lands disturbed by mining and associated activities for the northern Great Plains resource program. 20 p. U.S. Environ. Protec. Agency, Rocky Mountain-Prairie Reg., Denver, Colo.

86. U.S. Fish and Wildlife Service.
1977. The ecological effects of coal strip-mining: a bibliography with abstracts. U.S. Fish and Wildlife Serv. FWS/OBS-77/09, 416 p.

87. University of Arizona, Office of Arid Land Studies.
"SEAMALERT" - current, surface-mined reclamation literature alerting service. Univ. Ariz., Off. Arid Land Stuides, Tucson.

88. University of Pittsburgh.
1972. A selected bibliography and discussion of the effects of strip mining upon navigable waters and their tributaries. 94 p. Prepared for U.S. Dep. Army, Corps of Eng., by Grad. Center for Public Works Admin., Univ. Pittsburgh, Pittsburgh, Pa.

89. Van Alphen, J. G., and L. F. Abell.
1967. Annotated bibliography on reclamation and improvement of saline and sodic soils (1966-1970). Int. Inst. for Land Reclam. and Improve., Biblio. No. 6, 43 p. The Netherlands.

90. Vories, K. C., ed.
1976. Reclamation of western surface mined lands. [Workshop at Colo. State Univ., Fort Collins, March 1-3, Proc.] 152 p. ECO Consultants, Inc., Fort Collins, Colo.

91. Vories, K. C., and P. L. Sims.
1977. The plant information network. Vol. IV: a subject guide and annotated bibliography of selected literature on land reclamation and rehabilitation in the United States. p. 161-232. Colo. State Univ., Fort Collins.

92. Weiss, N. E., A. A. Sobeck, and D. L. Streib.
1977. A selective bibliography of surface coal mining and reclamation literature. Vol. 1: eastern coal province. 158 p. Argonne National Laboratory, Argonne, Ill.

93. Wewerka, E. M., J. M. Williams, P. L. Wanek, and J. D. Olsen.
1976. Environmental contamination from trace elements in coal preparation waste: a literature review and assessment. N.Mex. Energy Res. and Develop. Admin., Los Alamos Sci. Lab., No. LA-6600-MS, 61 p.

94. Western Regional Coordinating Committee.
1975. Bibliography pertaining to vegetation establishment and management on lands disturbed by mining in the western states. In Massive displacement of land from coal and oil shale development. West. Reg. Coord. Comm., WRCC-21, 6 p.

B. Current Research and Papers

Citations in section B were selected from the following sources: (1) Current research as described in responses to the survey inquiry letter. (2) Current papers (in press and unpublished reports) obtained from responses to survey letter. (3) Citations from file 60, "Curren Research Information" (Lockheed "Dialog"). (4) Citations from data file, "Research in Progres (RECON data vendor). The citations are grouped in the index by subject matter and/or impacts.

95. Archer, V. E., E. Radford, and O. Axelson.
1978. Radon daughters cancer in man. Presented to the Health Physics Society, June 19-23, 1978. (unpubl.)

96. Armiger, W. J.
1979. Revegetation of surface mined areas. Beltsville, Md.

97. Berg, W. A.
n.d. Vegetative stabilization of Paraho spent oil shale. (A mathematical model of salt and water transport.) Colo. State Univ., Fort Collins.

98. Berg, W. A.
n.d. Vegetative stabilization of spent oil shale. (Field studies involving establishment and the monitoring of native plant cover.) Colo. State Univ., Fort Collins.

99. Bjugsted, A. J.
n.d. Adaptability of selected tree and shrub species on bentonite mine spoils, Crook County, Wyoming and Butte County, South Dakota. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

100. Bjugsted, A. J.
n.d. Basin morphometry of strip mine ponds compared to stock ponds in the northern Great Plains. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

101. Bjugsted, A. J.
n.d. Influence of small mammals in the rehabilitation of areas disturbed during open pit mining. South Dakota Sch. Mines and Technol., Rapid City.

102. Bjusted, A. J.
n.d. Invertebrate species, abundance and standing crop biomass in strip mine ponds compared to stock ponds in the northern Great Plains. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

103. Bjugsted, A. J.
n.d. Nongame bird habitat associated with mine haul roads and surface mining for bentonite clay. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

104. Bjugsted, A. J.
n.d. Survival and growth of containerized vs. bare root shrub and tree planting stock on bentonite spoils in northeastern Wyoming. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

105. Bjugsted, A. J.
n.d. The synthesis of information to develop guidelines for managing strip mine water impoundments. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

06. Bjugsted, A. J.
n.d. Time trend changes in physiochemical properties of emplaced bentonite mine spoils near Colony, Wyoming. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

07. Bjugsted, A. J.
n.d. Water quality in strip mine ponds compared to stock ponds in the northern Great Plains. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

08. Bjugsted, A. J.
n.d. Waterfowl use of water impoundments left by strip mining in the northern High Plains. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

09. Brown, R. W.
1979. Revegetation of disturbed alpine tundra rangelands. (Abstr.) 32nd Annu. Meet., Soc. Range Manage., Casper, Wyo. p. 20.

10. Brown, R. W.
n.d. Effect of different revegetation techniques on successional trends on mine spoils. Utah State Univ., Logan.

11. Brown, R. W., T. Box, and P. Howard.
n.d. Evaluation of mining and post mining management on plant succession in natural ecosystems. Utah State Univ., Logan.

12. Carroll, R. E.
n.d. Wildlife and wildlife habitat survey - Glasgow. Ecological Consulting Service, Helena, Mont. [Baseline ecological survey including bentonite mined areas.]

13. Carroll, R. E.
n.d. Wildlife and wildlife habitat survey - Malta. Ecological Consulting Service, Helena, Mont. [Baseline ecological survey for bentonite mining areas.]

14. Chappell, W. R.
n.d. Toxic trace elements associated with shale oil production. Colo. State Univ., Boulder.

15. Costello, J.
n.d. Mortality of metal miners in the United States. Natl. Inst. for Occupational Safety and Health, Rockville, Md. [A survey and study of occupational health hazards relating to metal miners.]

16. Dean, K., and R. Davis.
1971. Vegetative stabilization of mill tailings using municipal and mineral wastes. Paper presented at the Environmental Quality Conference for the Extractive Industries, AIME [Washington, D.C., June 7-9, 1971].

17. Dean, K. C., and R. Havens.
1972. Reclamation of mineral milling wastes. Paper presented at the Annu. AIME Meeting [San Franciso, Calif., Feb. 21-24, 1972].

18. Dean, K. C., R. Havens, and E. G. Jaldez.
1970. Progress in using and stabilization of mineral wastes. Paper presented at the AIME Meeting [St. Louis, Mo., Oct. 21-23, 1970].

19. Dudley, R. F.
n.d. Machinery for establishment and maintenance of pasture and hay land in the East. Crop Production Engineering, Beltsville, Md. [Special machinery has been developed for deep placement of soil amendments into mine spoil banks.]

120. Eddleman, L. E.
n.d. Regeneration of indigenous species including germination and establishment in stress environments. Univ. Mont., Missoula.

121. Eddleman, L., and P. L. Meinhardt.
[In press.] Seed viability and seedling vigor in selected prairie plants. In Proc. 6th North Am. Prairie Conf. [Ohio State Univ., Columbus, Aug. 13-16, 1978].

122. Eno, C. F.
n.d. Preliminary non-projected research in soils. Univ. Florida, Gainesville. [Experiments were initiated to study three facets of reclamation: (1) slime dewateri by evapotranspiration, (2) amendment and fertilization of dry slime, and (3) amendme and fertilization of sand tailings. Results indicate successful reclamation of sand tailings by addition of dry slime (colloidal phosphate), sewage sludge, and fertilizers.]

123. Farmer, E. E., and B. Z. Richardson.
n.d. Performance of individual species in various grass mixtures growing on mine (Montana coal, Idaho phosphate and Idaho heavy metal) overburden piles. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

124. Farmer, E. E., and B. Z. Richardson.
n.d. Snowpack influences on acid mine drainage (in the West). USDA For. Serv., Interm For. and Range Exp. Stn., Logan, Utah.

125. Farmer, E. E., B. Z. Richardson, and P. E. Packer.
n.d. Effect of revegetation on acid production within a mine overburden. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

126. Ferguson, R. B.
n.d. Evaluation of copper tolerant clones of *Agrostis* spp. on spoil areas at the Kennecott copper mine in central Utah. USDA For. Serv., Intermt. For. and Range Exp. Stn., Provo, Utah.

127. Ferguson, R. B., S. B. Monson, and P. Grubaugh.
n.d. Plant species adaptability trials on copper mine spoils in central Utah (Kennecot USDA For. Serv., Intermt. For. and Range Exp. Stn., Provo, Utah.

128. Frischknecht, N. C., R. B. Ferguson, and P. E. Packer.
n.d. Develop recommendations, guidelines, and criteria for revegetation of coal and oil shale spoils on semi-arid lands. USDA For. Serv., Intermt. For. and Range Exp. Stn., Provo, Utah.

129. Ford, Bacon, and Davis, Inc.
n.d. Evaluation of radiation contamination from various sources and alternative dispos possibilities for the confinement of radiological wastes. Salt Lake City, Utah.

130. Galloway, W. E.
n.d. Predicting response of a natural system to uranium extraction, Oakville aquifer system, Texas. Tex. Univ., Austin.

131. Harvey, S., and T. Weaver.
1979. Reproductive biology of four *Artemisia* species with emphasis on revegetation. (In rough draft form.) Mont. State Univ., Bozeman.

132. Hawkes, C. L.
n.d. Selected literature related to aquatic impoundments on semi-arid regions: an annotated bibliography providing a basis for designing and managing American Northe Great Plains strip mine ponds for aquatic habitats and agricultural use. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

33. Hawkes, C. L.
n.d. A survey of the aquatic habitat of existing coal and bentonite clay strip mine ponds in the northern Great Plains: a basis for design and management decisions: an overview. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

34. Hawkes, C. L., and M. T. Anderson.
n.d. Water quality of 43 selected northern Great Plains impoundments including coal, bentonite clay strip mine ponds, and livestock ponds. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

35. Henry, C. D.
n.d. Trace and potentially toxic elements associated with uranium deposits of South Texas. Texas Univ., Austin.

36. Hughes, H., and Associates.
1966. Feasiblity report, channel improvement and erosion control, Railroad and Copper Creeks, vicinity of Holden Village, January 28, 1966. 22 p. H. Hughes and Associates. An "open file" report to USDA For. Serv., Wenatchee, Natl. Forest, Wenatchee, Wash.

37. Hunt, W. A., and D. Cowger.
1977. Program development for measurement of erodibility of spoil banks and untreated topsoil due to wind action. Unpubl. rep., USDA For. Serv., Intermt. For. and Range Exp. Stn., Bozeman, Mont.

38. International Minerals and Chemical Corporation.
1978. Water management in phosphate mining at IMC, Lakeland, Florida. Unpubl. rep. 20 p. Int. Min. and Chem. Corp., Lakeland, Fla. [Water management and conservation are important goals of this corporation. Water use is preplanned. The concepts of water recirculation, zero net withdrawal from the Floridan Aquifer, controlled surface runoff, superior flood control, zero process discharge, and water cropping are explained. Many of these are goals of the corporation and incorporated into their water management plan.]

39. Jurgensen, M. F.
n.d. Microorganisms of inoculated rhizosphere soil on copper mine tailings. Mich. Tech. Univ., Houghton.

40. Kennington, G. S., and J. E. Doerges.
n.d. Report on bioassays of radium-226 uptake in selected plants and animals at the Highland Uranium Mine, Wyo. Wyo. Dep. Environ. Qual.

41. Landa, E. R.
1978. The migration of radionuclides for uranium mill tailings - earth science perspectives
Unpubl. rep., Uranium Information Network.

42. Lewis, M. A.
n.d. Selected heavy metals in sediments and biota from desert streams of the Gila River drainage (Arizona). Proctor and Gamble Co.

43. Lindsey, D.
n.d. Development of techniques to establish mycorrhizal associations with plants used to revegetate strip-mined lands. N.Mex. State Univ., Las Cruces. [This association, in a number of cases, has increased growth and survival of plants on disturbed areas.]

44. Linder, R., and T. Schard.
n.d. Non-game bird habitat associated with haul roads and surface mining for bentonite clay. S.Dak. State Univ., Brookings.

145. Lochstet, W. A.
1979. An analysis of the proposed White Mesa uranium project. Unpubl. rep., Feb. 1979, to the Nuclear Regulatory Commission.

146. Ludeman, W. W.
n.d. Study plan for use of wood residue soil amendments for reclamation of bentonite mine spoils in N.E. Wyoming. Wyo. State For. Div.

147. McKell, C. M.
n.d. Rehabilitation of disturbed sites and processed oil shale disposal piles. Final rep. of research by Inst. for Land Rehabilitation, Utah State Univ., Logan. [Researc sponsored by White River Shale Project, Vernal, Utah.]

148. McMillion, L. G.
n.d. Energy related groundwater monitoring and techniques development. Environ. Protec. Agency, Las Vegas, Nev. [Including monitoring the change in groundwater quality as a result of oil shale mining.]

149. Mead, R. W., and A. V. Kneese.
n.d. Non-ferrous mining industry. Univ. N.Mex., Albuquerque. [Analysis of the enviro mental problems of the non-ferrous metal mining industry.]

150. Melfi, S. H., and D. N. McNelis.
n.d. Western energy environmental monitoring study. Environ. Protec. Agency, Las Vegas, Nev. [Involves the assessment and the development of monitoring techniques of energy related impacts.]

151. Miller, E. V.
n.d. Control technology for mine reclamation. U.S. Dep. Health and Welfare, Food and Drug Admin., Washington, D.C. [Includes surface manipulations and vegetation trials related to specific problems of reclamation sites.]

152. Miller, J.
n.d. Environmental and health effects. Unpubl. rep., Uranium Information Network. [The paper discusses the environmental and health effects of uranium mining and milling wastes. An extensive bibliography is included.]

153. Monson, S. B., and B. Z. Richardson.
n.d. Tree and shrub planting techniques on mine spoils. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

154. Montana Department of State Lands.
n.d. Bentonite mining related reclamation problems in the northwestern states. Helena, Mont.

155. O'Boyle, P.S.
1978. Report on the investigation of aquifer systems and geologic models for aquifer-recharge in the upper San Miguel drainage basin, Telluride area. 6 p. Unpubl. rep. submitted to Town Board of Telluride, Colo., Jan. 1978. [This report deals with systemic geologic conditions in the Upper San Miguel Drainage Basin and the way geologic structure, stratigraphy, lithology, and geochemistry affect the movement o surface and ground water. The report documents and describes the nature of surface and subsurface water and solute transport and details the results of geochemical, geophysical, hydrological, hydraulic, and geologic investigations within the area o interest.]

156. O'Bryan, C. L.
n.d. Technical literature searches [includes oil shale]. Current research, Bibliogra y Service, Univ. N.Mex., Albuquerque.

57. Orr, H. K.
n.d. Survival and growth of selected tree and shrub species on bentonite mine spoils near Colony, Wyoming and associated spoil characteristics. S.Dak. Sch. Mines and Technol., Rapid City.

58. Orr, H. K., A. J. Bjugsted, and R. Kerbs.
n.d. Survival and growth of containerized vs. bare root shrub and tree planting stock on bentonite spoils in northeast Wyoming. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Rapid City, S.Dak.

159. Packer, P. E.
n.d. Mine spoil reclamation in the Intermountain and Northern Rocky Mountain regions (WMR). USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

160. Potter, L. D.
n.d. A study of the inhibitive factors of mancos shale for plant growth. Univ. N.Mex., Albuquerque.

161. Potter, L. D.
n.d. A study of radon emission from uranium mill tailings as related to cover and vegetation. Univ. N.Mex., Albuquerque.

162. Richardson, B. Z.
n.d. Physical, chemical and biological properties of spoil materials from phosphate surface mining that inhibit growth. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah. [Current research.]

163. Richardson, B. Z.
n.d. Methods and techniques for the establishment of grass on steep slopes. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

164. Richardson, B. Z.
n.d. Reduction of high sodium content in western coal mine spoils with time. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

165. Richardson, B. Z.
n.d. Use of organic soil amendments in the revegetation of heavy metal surface mined areas. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

166. Richardson, B. Z., and E. E. Farmer.
n.d. The establishment of vegetation on high sodium content mine spoils -Decker, Montana. USDA For. Ser., Intermt. For. and Range Exp. Stn., Logan, Utah. [Current research.]

167. Richardson, B. Z., and E. E. Farmer.
n.d. Evaluation of straw and wood fiber as mulching materials on surface mined areas in the West. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

168. Richardson, B. Z., and E. E. Farmer.
n.d. Physical, chemical and biological properties of spoil materials resulting from toxic, heavy metals mining that inhibit plant growth. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah. [Current research.]

169. Richardson, B. Z., and E. E. Farmer.
n.d. Hydromulching as an alternative mulching method on high sodium surface mine disturbances. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

170. Richardson, B. Z., and E. E. Farmer.
n.d. Physical, chemical and biological properties of spoil materials resulting from Idaho phosphate mining that inhibit plant growth. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

171. Richardson, B. Z., and E. E. Farmer.
n.d. Species adaptability on Idaho phosphate, Montana coal and Idaho heavy metal spoils: assess by greenhouse bioassay techniques. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

172. Richardson, B. Z., and E. E. Farmer.
n.d. Chemical treatments, hydraulic planting and mulching as a revegetation method on steep overburden piles. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

173. Richardson, B. Z., E. E. Farmer, and R. W. Brown.
n.d. Establishment of vegetation on phosphate surface mine spoils at the Ballard Mine, Idaho. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

174. Russell, K. R.
1978. Overview of a proposal to prepare alternative wildlife replacement plans in response to phosphate resource development, southeastern Idaho. [Unpubl. proposal.]

175. Russo, R. C., R. V. Thurston, and R. K. Skogerboe.
n.d. Toxic effects on the aquatic biota from coal and oil shale development. Mont. State Univ., Bozeman.

176. Sabey, B. R., A. J. Bjugsted, and C. E. Boldt.
n.d. Use of wood chip as a mulch in the reclamation of bentonite mine spoils. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Rapid City, S.Dak.

177. Sanks, R. L.
1977. The use of municipal sludge and municipal solid waste as soil amendments. Final rep. to USDA Forest Service. [The findings were that growth was greatly enhanced and comparable to growth obtained by the use of stripped and reclaimed topsoils.]

178. Scott, R. B.
n.d. Evaluation of 3 permeable limestone seals via construction of 3 eastern dams. Environ. Protec. Agency, Cincinnati, Ohio. [The limestone in the seal will react with the acid water to neutralize acidity and to precipitate ferric and aluminum hydroxides that will tend to plug the voids between stones and prevent water flow.]

179. Shen, H. W.
n.d. Erosion effects and pollutant movements from coal and oil shale strip-mining deposition. Colo. State Univ., Fort Collins.

180. Shetron, S. G.
n.d. Mine waste rehabilitation - non-metallic mines. Mich. Tech. Univ., Houghton. [Revegetation of limestone wastes - future studies will include other non-metal mines.]

181. Simes, P. L.
n.d. Reclamation of mining wastes in south central Colorado. Colo. State Univ., Fort Collins. [Includes colomite and limestone mining wastes.]

182. Skaptason, J. B.
n.d. Determination of natural recurrence of soil decomposer populations on reclaimed mine areas. Western Energy and Land Use Team, Off. Biol. Serv., U.S. Dep. Interior, Fish and Wildlife Serv., Fort Collins, Colo.

183. Smalley, G. H., P. T. Tueller, and E. L. Miller.
n.d. Revegetation of copper mine tailings and overburden in eastern Nevada. Unpubl. ms., Div. Renewable Nat. Resour., Univ. Nevada, Reno. 66 p.

84. Sorensen, D. L., D. B. Procella, and B. Z. Richardson.
n.d. Established microbial population in spoil materials of selected saline characterized surface mines. Utah State Univ., Water Res. Lab., Logan.

85. Southern California Rock Products.
1978. Model: sand and gravel mining operation. (Unpubl. rep.) [This paper documents sand and gravel mining operations in Southern California and the reclamation programs for each operation. In some cases, reclamation is complete--a new park or housing development. In other cases, the reclamation program is in planning stages.]

86. Thorsen, G. W.
1970. Holden tailings. Wash. State Dep. Nat. Resour., Div. Mines. Unpubl. rep. [Mar. 3, 1970].

87. Thurston, R. V.
n.d. Toxic effects on the aquatic biota from coal and oil shale. Florida Inst. Tech., Jensen Beach.

88. Thurston, R. V., R. C. Russo, and R. K. Skogerboe.
n.d. Toxic effects on the aquatic biota from coal and oil shale development. Mont. State Univ., Bozeman, and Colo. State Univ., Fort Collins.

89. Tinlin, R., and L. G. Everett.
n.d. Groundwater research monitoring of energy related developments. General Electric Co., Santa Barbara, Calif. [Development of groundwater monitoring model and strategy.]

90. USDA Agricultural Research Service.
n.d. Revegetation of areas disturbed by man in the central high plains with trees, shrubs, and other woody plants. USDA Agric. Res. Serv., Cheyenne, Wyo.

91. Uresk, D., and T. Yamamoto.
1979. Growth of plants on bentonite spoil under greenhouse conditions. Paper presented at 1979 annu. meet., Soc. Range Manage. [Casper, Wyo., Feb. 12-16, 1979]. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins.

192. Weir, D. N.
1977. Water use and treatment at a placer gold mining site in relation to the local distribution of some anadromous fishes. Unpubl. rep., Tuluksak Dredging Ltd., Nyal, Bethal, Alaska. [This report describes the reduction of process water turbidity in 1976 at a placer gold dredging site on the Tuluksak River, in the Kilbuck Mountains of southwestern Alaska, in compliance with draft Environmental Protection Agency regulations. It also assesses mining activities in relation to the local spawning distribution of king salmon, *Ochorynchus tshawytscha*, and includes notes on some other salmonid fishes. The study was made in close consultation with officers of the Alaska Department of Fish and Game. It was funded by the dredging company and by the Placer Miners Committee of the Alaska Miners Association.

193. Weir, D. N.
1978. Environmental considerations in new placer mine proposals in the Candle Area, Alaska. 16 p. Unpubl. rep. for C. C. Hawley and Associates, Inc. [The report notes some environmental factors and describes features of the ecosystem, including past human impact. Assuming any new mining would be in Candle Creek, the inner Kiwalik Flats, or on Mud Creek, the report also considers for each site water treatment relative to environmental regulations, the revegetation of disturbed ground, and possible wider effects on widllife. Information collected in the reconnaissance period is only summarized here.]

194. Wienke, C. L.
n.d. Ecological investigation of rehabilitation of uranium mine tailings of the southeastern U.S. Los Alamos Sci. Lab., N.Mex. [Rehabilitation/stabilization alternative discussed and evaluated.]

195. Willard, B. E., and R. William.
n.d. 20 years of recovery of alpine tundra following protection from visitors, Trail Ridge, Rocky Mtn. Nat'l. Park, Colorado. Colo. Sch. Mines. [Current research.]

196. Wuilstein, L. H.
n.d. Evaluation of plant growth in covered and uncovered radioactive mine tailings (VITRO) in relation to control and radon emissions. Univ. Utah, Salt Lake City.

197. Yamamoto, T., and A. J. Bjugsted.
n.d. Trend-surface analysis of Powder River Basin, Wyoming, Wyoming-Montana, and Williston Basin, North Dakota. S.Dak. Sch. Mine Technol., Rapid City.

198. Yamamoto, T., and D. Uresk.
n.d. Growing shrub and tree species on bentonite spoil under greenhouse (part 1) and field (part 2) conditions. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins.

C. Land Use Planning and Public Policy

Section C contains citations that relate to land-use planning and public policy. Planning in mining and reclamation requires previous land use decisions. Federal and State guidelines for land-use decisions and public policy in reclamation are included.

199. Amir, S.
1975. Surface gravel excavation and environmental quality: a resource management policy. J. Environ. Manage. 3(2):77-89.

200. Bamberg, S. A.
1975. Approaches to large scale land reclamation in oil shale development. In Environmental Oil Shale Symposium Proc. [Oct. 9-10]. p. 95-103. J. H. Gary, ed. Colo. Sch. Mines, Quarterly 70(4). 244 p.

201. Berklund, C.
1974. Managing the public lands for minerals--energy. In Pac. Southwest Energy and Minerals Conf. Proc. [Nov. 11, 1974, Denver, Colo.]. U.S. Dep. Interior, Bur. Land Manage., Denver, Colo.

Some priorities in land management as seen today are discussed. New dealings with land management are examined. The current and proposed programs of the Bureau of Land Management (BLM) are designed to assure adequate supplies of fossil fuels and minerals, and include development of outer continental shelf areas, transportation of Alaska oil and gas, oil shale leasing programs in the western U.S., leasing of Federal coal reserves, and development of a management tool for leasing coal resources on public lands; these programs follow congressional actions on surface mining and air quality regulations. The opportunity for new energy and mineral resources lies in BLM's land-use planning system with no legislation for national policy and guidelines to manage national resource lands properly. Legislation dating back over a hundred years has resulted in some 3,000 laws; these have resulted in conflicts and environmental impacts. The production of nonenergy minerals is failing to meet demand, but BLM is attempting to provide a harmonious relationship between mineral development and protection of other resources on the public domain.

202. Carroll, T. E.
1972. Updating the policies and activities of the Environmental Protection Agency as related to the mining industry. Mining Congr. J. 58(12):61-63.

203. Copeland, O. L., and P. E. Packer.
1972. Land use aspects of the energy crisis and western mining. J. For. 70(11): 671-675.

204. Duesterhaus, R. L.
1970. Gravel pit today, subdivision tomorrow. Soil Conserv. 36(2):32-33.

205. Ellis, S.
1977. Guide to land cover and use classification systems employed by western governmental agencies. Ecology Consultants, Inc., Fort Collins, Colo. 184 p. [Available NTIS as PB-265 173/AS.]

206. Gist, C. S., and others.
1975. A simple method for evaluating alternatives to a proposed environmental alteration: its history, and an example of its use in oil shale development. Colo. Sch. Mines Quarterly 70(4):29-74.

207. Graves, F. M., and others.
1977. Energy, public choices, and environmental data needs. Inst. Public Admin. and Natl. Wildl. Fed. 61 p. [Available NTIS as PB-272-263.]

208. Guernsey, J. L., L. A. Brown, and A. O. Perry.
1978. Integrated mined-area reclamation and land-use planning, vol. 3C. A case study of surface mining and reclamation planning. 122 p. Georgia Kaolin Company Clay Mines, Washington County, Ga. [Available NTIS as ANL/EMR-1 (V.3C).]

The case study examines the reclamation practices of the Georgia Kaolin's American Industrial Clay Company Division, a kaolin producer centered in Twiggs, Washington, and Wilkinson Countie Georgia. The State of Georgia accounts for more than one-fourth of the world's kaolin production and about three-fourths of the U.S. kaolin output. The mining of kaolin in Georgia illustrates the effects of mining and reclaiming lands disturbed by area surface mining. The disturbed areas are reclaimed under the rules and regulations of the Georgia Surface Mining Act of 1968. The natural conditions influencing the reclamation methodologies and techniques are markedly unique from those of other mining operations. The environmental disturbances and procedures used in reclaiming the kaolin mined lands are reviewed and implications for planner are noted.

209. Hansen, R. P., W. A. Hillhouse II, B. E. Willard, and others.
1970. Public land policy and the environment, vol. 2, part II: Environmental problems on the public lands. Summary statement and case studies 1 through 8. 409 p. Rocky Mountain Center on Environment, Denver, Colo. [Available NTIS as PB-196 169.]

Volume 2 of the study on public land policy and the environment contains eight case studies, each of which discusses land uses or management practices on public lands having environmental consequences and an initial summary chapter which draw together the overall implications of these studies and those contained in vol. 3 (part 2 continued) of the report.

210. Hill, A. D.
1973. Pave old gravel pit: town gets sanitary land fill. Roads and Streets 116(8):104

211. Imhoff, E. A., T. O. Firz, and J. R. LaFevers.
1976. A guide to State programs for the reclamation of surface mined areas. U.S. Dep. Interior, Geol. Surv. Circ. 731, 33 p.

The status, content, and general trend of State programs for the reclamation of surface mined areas is discussed.

212. LaFevers, J. R. , L. A. Brown, and R. C. Fountain.
1977. Integrated mined-area reclamation and land use planning, vol. 3B. Argonne National Lab., Ill. 71 p. [Available NTIS as EMR-1(V.3B).]

The reports in this series are designed primarily to familiarize professional land use and resource planners with the range of possibilities and effective procedures for achieving integrated mining, reclamation, and land-use planning. These reports are based on a research program which included an extensive literature review, the compilation and analysis of case study data, and close coordination and interaction with related government programs. In volume 3, A Guide to Mined Area Reclamation Technology for Reclamation and Land Use Planners, the methods used to reclaim land in each of several mineral industries are discussed in relati to the physical and cultural constraints that must be considered in planning a reclamation program. Much of the information for this document was obtained from case studies conducted in several mining districts. Volume 3B presents data from a case study of surface mining and reclamation planning, International Minerals and Chemical Corporation, Phosphate Operations, Polk County, Fla.

213. Landerman, N. J., S. Schwartz, and D. R. Tapp.
1972. Community resource: the development-rehabilitation of sand and gravel lands. Calif. State Polytech. Univ., Pomona, Sch. Environ. Design, Dep. Landscape Architectu 63 p.

214. Lewis, L. R., A. O. Perry, and J. R. LaFevers.
1977. Integrated mined-area reclamation and land use planning, vol. 3A. Argonne National Lab., Ill. 96 p. [Available NTIS as ANL/EMR-1(V.3A).]

This case study details reclamation planning for the Flatiron Companies' South Boulder Creek Park Project in Boulder, Colo. The site contains a deposit of high-quality sand and gravel considered to be one of the best and largest known deposits of aggregate materials in the Front Range area. The aggregate deposit is located in a highly visible site just off the Denver-Boulder Turnpike at the entrance to the city from Denver, and adjacent to a residential portion of the city. In order to make maximum use of premining planning, as a tool for resolving a conflict over the company's proposed operation, an extensive cooperative planning effort was initiated. This included the preparation of an environmental impact assessment, numerous public hearings, operating and reclamation plan review by city authorities, annexation of the site to the city, and the granting of a scenic easement on the property to the city for the development of a regional recreation park. A suite of contractual agreements was worked out among Flatiron Companies, the City of Boulder, the Colorado Open Lands Foundation, and the Federal Bureau of Outdoor Recreation. The purpose of this case study is to allow the planner to gain insight into the procedures, possibilities, and constraints involved in premining planning in a cooperative situation.

215. Matter, F. S., and others.
1974. A balanced approach to resource extraction and creative land development associated with open-pit copper mining in southern Arizona. 85 p. Univ. Ariz., Tucson, Coll. Architecture, Coll. Mines.

216. Moore, R., and T. Mills.
1977. Federal leasable and locatable mineral regulations: an environmental guide for resource managers. 84 p. Ecology Consultants, Inc., Fort Collins, Colo. [Available NTIS as PB-272 153/8GA.]

This report contains a compilation of Federal environmental regulations pertaining to surface mining operations in three geomorphic regions of the western United States: Northern Great Plains Region, Rocky Mountain Region, and Intermountain and Arid Southwest Regions. Specific minerals covered are: coal, oil shale, phosphate, bentonite, copper, gypsum, and uranium. Aspects of surface mining are presented in horizontal flow diagrams with application points of the aforementioned regulations illustrated. Particular emphasis is given to points of application where agency input regarding protection of fish and wildlife values is possible.

217. Oxford, T. P., and L. G. Bromwell.
1977. Planning for phosphate land reclamation, Central Florida. Proc., Conf. on Geotech. Pract. for Disposal of Solid Waste Matter [Univ. Mich., Ann Arbor]. p. 715-726. Am. Soc. Civil Eng., New York.

This paper describes considerations involved in the development of a life-of-mine plan for the disposal of wastes and the restoration of land to beneficial use for a future mining tract in central Florida. The arrangement and cost of waste clay settling areas, minimization of disturbance to unminable areas, the interface between the operation and the surrounding community, the presence of wetland areas, and the selection of reclamation techniques are among the concerns that are addressed.

218. Paone, J., J. L. Morning, and L. Giorgetti.
1974. Land utilization and reclamation in the mining industry, 1930-71. U.S. Bur. Mines, Rep. No. Bumines-1C-8642, 68 p. Washington, D.C. [Available NTIS as PB-233 955/4.]

Land utilized by the mining industry from 1930 through 1971 amounted to 3.65 million acres, or 0.16 percent of the land mass in the United States. Land reclaimed during the same period was 1.46 million acres, or 40 percent of the land utilized. This report includes data on land use for wastes from underground and surface mining, for wastes from mill operations, and on subsidence. Data on land use and reclamation were obtained from operating companies, mining organizations, appropriate State agencies, and others concerned with such activities.

219. Parker, H. D.
1974. Remote sensing for western coal and oil shale development planning and environmental analysis. In Remote Sensing Applied to Energy Related Problems, Symposium [Miami, Fla., Dec. 2-4] Proceedings. p. S4:3-S4:25. T. N. Veziroglu, ed. Univ. Miami, Coral Gables, Fla.

220. Pickels, G.
1970. Realizing the recreation potential of sand and gravel sites. Research project of the Univ. of Illinois. 75 p. Natl. Sand and Gravel Assoc., Silver Springs, Md.

221. Rogers, W. L.
1975. The oil shale environmental advisory panel, the environment, and the Federal program: past, present and future. Colo. Sch. Mines, Quarterly 70(4):1-18.

222. Robertson, J. L.
1975. Dredging and reclamation plans govern Kenosha materials sand and gravel operation. Rock Products 78(4):42-45.

223. Rounsaville, H. D.
1977. Guidelines for estimating potential land capability and range sites as a part of reclamation planning and alternative analysis - Thunder Basin National Grasslands. 47 p. USDA For. Serv., Medicine Bow Natl. For., Laramie, Wyo.

Here is a guide for the estimation of potential reclaimed land capability and range sites for drastically disturbed lands. The guide is an adaptation of the procedures developed by the USDA Soil Conservation Service for land capability and range sites classification of natural soils and landscapes. The validity of the approach is dependent upon data accuracy and the output is in terms of predicted potentials.

224. Schellie, K. L., and A. M. Bauer.
1968. Shaping the land-planned use of industrial sand deposits. 46 p. Natl. Sand and Gravel Assoc., Silver Springs, Md.

225. Schellie, K. L., ed.
1977. Sand and gravel operations - a transitional land use. 212 p. Natl. Sand and Gravel Assoc., Silver Springs, Md.

This paper provides a valuable handbook on transitional land use. It includes chapters on environmental impact statements, preplanning, land use potentials, and site improvement practices. It gives practical guidelines, excerpts from reclamation rules and regulations as well as two research case studies (a wet and a dry site). Examples of industry programs are also given.

226. Swan, D.
1973. Relationship of the environment and public policy. Mining Congr. J. 59(2):74-76.

227. Teska, R. B.
1973. Where there's room for everything: a 234,500 acre plan in an old copper-mining region. Landscape Architecture 63(3):256-265.

228. Thames, J. L., T. R. Verma, and J. R. LaFevers.
1977. Integrated mined-area reclamation and land-use planning, vol. 3E: a case study of surface mining and reclamation planning; Asarco Open Pit Copper Mine, Casa Grande, AZ. Argonne National Laboratory, Ill. [Available NTIS as 78:006132.]

The reports in this series are designed primarily to familiarize professional land use and resource planners with the range of possibilities and effective procedures for achieving integrated mining, reclamation, and land-use planning. These reports are based on a research program which included an extensive literature review, the compilation and analysis of case study data, and close coordination and interaction with related government programs. This volume presents a case study of surface mining and reclamation planning at the ASARCO open pit copper mine, Casa Grande, Ariz.

229. Thieme, W. I.
1968. Gravel land zoning and rehabilitation. 7 p. Presented at Mich. Highway Conference [March 1968, Grand Rapids, Mich.].

Reclamation, in sand and gravel mining, is good business. Suggestions are given to help mitigate objectionable effects of the mining. Alternate land use ideas for eventual reclamation are also given.

230. Tully, W. P., and C. N. Lee.
1975. Hydrologic and environmental impact budgeting for a quarry tailings pond. In Watershed management. p. 80-95. Am. Soc. Civil Eng., New York.

231. Turcott, G.
1975. Minerals management on the public lands. In Rocky Mountain Energy-Minerals Conference Proc. [Billings, Mont., Oct. 15-16]. p. 8-19. U.S. Bur. Land Manage., Billings. 294 p.

232. U.S. Department of the Interior, Bureau of Outdoor Recreation.
1976. Preplanning: surface mining for outdoor recreation. 22 p. [Available GPO as I 66.2 SU7/2 or stock number 2416-00068.]

233. Williams, C. E., and Associates, Inc.
1972. The use of sand and gravel pits for sanitary landfills. 139 p. Natl. Sand and Gravel Assoc., Silver Springs, Md.

234. Wobber, F. J., and K. Martin.
1977. Aerial photographic and satellite image application. World Min. 3(4):53-57.

Based on tests conducted in Florida, large scale color and color infrared aerial photography are well suited for all types of phosphate mining analysis including mine design, and reclamation planning, inventory, impact assessments, and reclamation monitoring. Small scale aerial photography can be used for inventorying phosphate mined lands and associated land use features, such as tailing ponds. Repetitive satellite imagery provides an economical means of acquiring general reclamation data on a periodic basis. Satellite imagery has been successfully used to detect major phosphate mining and processing operations during preliminary analyses conducted in the Florida phosphate mining district.

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DOCUMENTS DEPT.

D. Economic and Legal Aspects

Section D presents reclamation and pollution control as components of a more complicated Citations dealing with the economic impact of reclamation and pollution control are included. included are citations on legal aspects which show existing and sometimes conflicting Federal, State, and local regulations.

235. Almond, M. A.
1975. Legal aspects of phosphate mining in North Carolina. 31 p. North Carolina Univ Chapel Hill, Sch. Law. [Available NTIS as COM-75-10504/9ST.]

The article presents the ecological dilemma in a complex setting. The removal of phosphate fr beneath navigable waters of North Carolina may produce adverse effects upon marine life adjace the operation. On the other hand, the phosphate is critically needed to provide fertilizer to increase crop yields in a hungry world. The ecological resolution of this scientific, economi legal, political, and humanistic problem is not simple. The author sets forth the pertinent N Carolina statutes and legal thinking likely to be used in the administrative or legal solution this problem. He points out that wide discretion is vested in State officials and that where several worthwhile interests are to be reconciled and where delicate policy decisions must be flexible regulation may well provide the only viable answers.

236. Arthur D. Little, Inc.
1978. Economic impact of environmental regulations on the United States copper industr 516 p. Arthur D. Little, Inc., Cambridge, Mass. [Available NTIS as PB-278 280/3GA.

This report estimates, by use of an econometric model, the economic impact of environmental re tions on the United States copper industry. The report covers the principal air and water reg as they affect copper mining, milling, smelting, and refining. Price, employment, production, net imports are forecast over the period 1978-1987 both with and without present environmental regulations.

237. Banks, C. E., R. I. Benner, L. L. Brannick, and others.
1975. Technical and economic study of an integrated single pass mining system for pit mining of deep oil shale deposits. 260 p. Sun Oil Co., Richardson, Tex. [Availabl NTIS as PB-250 525/3ST.]

Data were collected on the geology and hydrology of the Green River formation in the Piceance Basin, Colorado, on mining reclamation methods and cost, and on surface mining and crushing me and costs. Data were organized into tables, graphs, and flow charts for engineering analysis. from eight large surface mines and a preliminary mine layout for a pit producing 1.25 million per day are included in the report.

238. Carter, L. J.
1978. Uranium mill tailings: Congress addresses a long-neglected problem. Science 202 195.

239. Cook, C. F.
1978. Memorandum: (Environmental Aspects Subcommittee/COSMAR) Comments relating to prc list of environmental problems connected with mining. [Unpubl. rep. to COSMAR and t Southern California Rock Products.]

The memorandum accounts for the many existing Federal statutes, State statutes, Federal regula and programs now in existence or being implemented to deal with each environmental aspect ment in "Provisional List of Environmental Problems Connected with Mining," by Environmental Subcom COSMAR.

240. Davis, J. F.
1978. Carrying out the policy rules and regulations of the California Surface Mining a Reclamation Act (SMARA). Testimony presented to COSMAR panel on construction materi Nov. 2, 1978, Pasadena, Calif.

This paper is concerned with the reclamation of mined land in California under California's Surfac Mining and Reclamation Act of 1975 (SMARA). It covers the intent and mechanism of the Act itself, the performance of the several organizations responsible for carrying it out, and the results achie so far in its history. The paper also compares the mechanisms of SMARA with those of the Federal Surface Mining Control and Reclamation Act of 1977, PL95-87 (SMCARA). Finally, it discusses possib modifications of SMCARA to make it effective and reasonable, if it is to be applied to surface mining in California for minerals other than coal.

241. Mining Congress Journal.
1977. AMC and NCA testify on surface mining legislation. Mining Congr. J. 63(2):100-107.

242. Spence, H. M.
1975. Cost factors in environmental protection and planning. In Environmental Oil Shale Symposium Proc. [Oct. 9-10]. p. 75-87. J. H. Gary, ed. Colo. Sch. Mines, Quarterly 70(4). 244 p.

E. Effects on Air Quality

Section E includes citations on air pollution, monitoring, and control. Citations dealin with effects of air contaminants on health are included in section J and are cross-referenced in the index under "Air Effects."

243. Breslin, A. J., A. C. George, and M. A. Weinstein.
1969. Investigation of the radiological characteristics of uranium mine atmospheres. 43 p. New York Operations Office (AEC), New York Health and Safety Lab. [Available NTIS as HASL-220.]

244. Davis, W. E., and Associates.
1973. Emission study of industrial sources of lead and air pollutants. 133 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as RC A07/MF-A01.]

This report has been prepared to provide reliable information regarding the nature, magnitude, and extent of lead emissions from industrial sources in the United States for the year 1970. Background information concerning the basic characteristics of the lead industry has been assembled and included. Brief process descriptions, limited to areas closely related to existing or potential atmospheric losses of lead, are included. Lead emissions and emission factors are presented.

245. Davis, W. E., and Associates.
1972. National inventory of sources and emissions, barium, section I. 56 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-210-686.]

Information is provided regarding the nature, magnitude, and extent of the emissions of barium in the United States for the year 1969. Background information concerning the basic character istics of the barium (barite) industry has been assembled and included. Brief process descrip tions are given; they are limited to the areas that are closely related to existing or potenti atmospheric losses of the pollutant. Emissions to the atmosphere during the year were 15,420 tons. Nearly 18 percent of the emissions resulted from the processing of barite, more than 28 percent from the production of chemicals, 23 percent from the manufacture of various end products, and about 26 percent from the combustion of coal. The wear of rubber tires was a relatively minor emission source.

246. Davis, W. E., and Associates.
1972. National inventory of sources and emissions, boron, section II. 51 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-210 677.]

Information is provided regarding the nature, magnitude, and extent of the emissions of boron. Background information concerning the basic characteristics of the boron industry has been assembled and included. Process descriptions are given, but they are brief, and are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant. Emissions to the atmosphere during the year were 11,003 tons. Nearly 22 percent of the emissions resulted from the processing of boron compounds, more than 34 percent from the manufacture and use of various end products, and about 43 percent from the combustion of coal. Emission estimates for processing and the manufacture of end use products are based on unpublished data obtained from industrial sources.

247. Davis, W. E., and Associates.
1972. National inventory of sources and emissions, copper, section III. 74 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-210 678.]

Information is provided regarding the nature, magnitude, and the extent of the emissions of copper in the United States for the year 1969. Background information concerning the basic characteristics of the copper industry has been assembled and included. Brief process descri tions are given; they are limited to the areas that are closely related to existing or potent atmospheric losses of the pollutant. Emissions to the atmosphere during the year were 13,680 tons. About 64 percent of the emissions resulted from the metallurgical processing of primar opper, and about 20 percent from the production of iron and steel. The combustion of coal as the only other significant emission source.

48. Davis, W. E., and Associates.
1972. National inventory of sources and emissions, selenium, section IV. 57 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-210 679.]

nformation is provided regarding the nature, magnitude, and extent of the emissions of selenium n the United States for the year 1969. Background information concerning the basic characterstics of the selenium industry has been assembled and included. Brief descriptions are iven; they are limited to the areas that are closely related to existing or potential atmospheric osses of the pollutant. Emissions to the atmosphere during the year were 986 tons. The missions that resulted from the combustion of coal were about 65 percent of total emissions, nd those due to the manufacture of glass were nearly 21 percent. Emissions from metallurgical rocessing of nonferrous metals and the burning of fuel oil were 9 and 7 percent respectively, hile all other emissions were less than 1 percent of the total.

49. Davis, W. E., and Associates.
1972. National inventory of sources and emissions, zinc, section V. 85 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-210-680.]

nformation is provided regarding the nature, magnitude, and extent of the emissions of zinc n the United States for the year 1969. Background information concerning the basic characterstics of the zinc industry has been assembled and included. Brief process descriptions are iven; they are limited to the areas that are closely related to existing or potential atmospheric osses of the pollutant. Emissions to the atmosphere during the year were 159,922 tons. bout 31 percent of the emissions resulted from the metallurgical processing of zinc, more han 30 percent from the production of iron and steel, and nearly 18 percent from the incineraion of refuse. The production of zinc oxide, the wear of rubber tires, and the combustion of oal were also significant emission sources.

50. Davis, W. E., and Associates.
1970. National inventory of sources and emissions, cadmium, section I. 53 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-192 250.]

he aim is to provide reliable information regarding the nature, magnitude, and extent of the missions of cadmium in the United States for the year 1968. Background information concerning he basic characteristics of the cadmium industry has been assembled and included. Process escriptions are given, but they are brief, and are limited to the areas that are closely elated to existing or potential atmospheric losses of the pollutant. The apparent consumption as 13.3 million pounds, and domestic production 10.6 million pounds. Only a small amount of admium was recovered from scrap. Emissions to the atmosphere during the year totaled 4.6 illion pounds. Emissions from the metallurgical processing plants of the primary producers f cadmium, zinc, lead, and copper were more than 2 million pounds, and those from melting perations in the iron and steel industry were about the same. Emission estimates for mining, etallurgical processing, and reprocessing operations are considered to be reasonably accurate. hey are based on data obtained by personal contact with the processing and reprocessing ompanies.

51. Davis, W. E., and Associates.
1970. National inventory of sources and emissions, nickel, section II. 46 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-192 251.]

he aim is to provide reliable information regarding the nature, magnitude, and extent of the missions of nickel in the United States for the year 1968. Background information concerning he basic characteristics of the nickel industry has been assembled and included. Process escriptions are given, but they are brief, and are limited to the areas that are closely elated to existing or potential atmospheric losses of the pollutant. Consumption for the ear was reported to be 159,306 tons and domestic production to be 29,215 tons including the roduction from both primary and secondary sources. Imports, mostly from Canada, totaled

147,950 short tons. Emissions to the atmosphere during the year were 6,475 short tons. About 83 percent of the emissions were due to the burning of heavy fuel oil and coal. Estimates of emissions for mining, metallurgical processing, and reprocessing operations are based on data obtained by personal contact with processing and reprocessing companies, and are considered to be reasonably accurate.

252. Davis, W. E., and Associates.
1970. National inventory of sources and emissions, asbestos, section III. 56 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-192 252.]

The aim is to provide reliable information regarding the nature, magnitude, and extent of the emissions of asbestos in the United States for the year 1968. Background information concerni the basic characteristics of the asbestos industry has been assembled and included. Process descriptions are given, but they are brief, and are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant. The apparent consumptio for the year was 817,363 tons and the domestic production was only 120,690 tons. Imports, mostly from Canada, totaled 737,909 short tons. There was no recovery from scrap. Emissions to the atmosphere during the year were 6,579 tons. About 85 percent of the emissions were due to mining and milling operations. Estimates of emissions are based for the greatest part on observations made during field trips, and on the limited information provided by mining, milling, and reprocessing companies. Information was not available regarding the magnitude of the emissions on the locations visited.

253. Davis, W. E., and Associates.
1971. National inventory of sources and emissions, vanadium-1968. 62 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-221 655/4.]

An emission inventory has been prepared to determine the nature, magnitude, and extent of the emissions of vanadium in the United States for the year 1968. The production and use of vanadium in the U.S. has been traced and charted. The consumption was 5,495 tons, exports 741 tons, and imports 652 tons. About 80 percent was used in the production of steel. Emissions to the atmosphere during the year totaled 19,321 tons. Emissions due to the combustion of fuel oil and coal were 17,000 tons and 1,750 tons, respectively. Emissions resulting from the production of ferrovanadium were 144 tons and those from the production of steel were 236 tons.

254. Douglas, G. W., and A. C. Skorepa.
1976. Monitoring air quality with lichen: a feasibility study. Douglas Ecological Consultants Ltd., Environ. Res. Mongr. 1976-2, 69 p.

A study was undertaken in 1975 to determine the scientific, technical, and economic feasibili of establishing air pollution effect gradients using lichenological methods on a radially arranged pattern of observation sites. The data acquired from 12 lichen sample plots indicat that the flora are sufficiently rich and widespread to allow establishment of a lichen air quality monitoring system. A grid network, containing 56 permanent plots, will provide adequ coverage of the region. Partial resurveys should be conducted annually, at least during the first years of the Syncrude plant's operation. Complete resurveys will only be required if a partial resurvey indicates adverse changes are occurring.

255. Engineering and Mining Journal.
1976. The asbestos industry: facing up to strict emissions limitations. Eng. and Mining J. 177(10):37.

256. Environmental Protection Agency.
1973. Control techniques for asbestos air pollutants. 104 p. Environ. Protect. Agency, Research Triangle Park, N.C. [Available NTIS as PB 222 020/0.]

The report contains information about the nature and control of a hazardous air pollutant--asbestos. The primary purpose of this document is to provide information useful to those involved in the control of emissions of asbestos from industrial sources. The language and pproach are largely technical, but the first two sections should be of interest and value to he general reader. The contents include the following: asbestos emission sources; control echniques and control cost (mining, milling, manufacture, and uses of products, disposal of sbestos waste); costs of control by gas cleaning devices; evaluation of asbestos emissions; nd development of new technology.

57. GCA Corporation.
1973. National emissions inventory of sources and emissions: molybdenum. 36 p. GCA Technology Div., Bedford, Mass. [Available NTIS as PB-230 035/8.]

national inventory of the sources and emissions of the element molybdenum was conducted. he study indicated the preparation of an overall material flow chart depicting the quantities f molybdenum moving from sources of mining and importation through all processing and reprocessng steps to ultimate use and final disposition. All major sources of molybdenum-containing missions were identified and their molybdenum emissions into the atmosphere estimated. A egional breakdown of these sources and their emissions was also provided. The physical and hemical nature of the molybdenum-containing emissions was delineated to the extent that nformation was available, and a methodology was recommended for updating the results of the tudy every 2 years.

58. GCA Corporation.
1973. National emissions inventory of sources and emissions of silver. 43 p. GCA Technology Div., Bedford, Mass. [Available NTIS as PB-231 368/2.]

national inventory of the sources and emissions of the element silver was conducted. The tudy included the preparation of an overall material flow chart depicting the quantities of ilver moving from sources of mining and importation through all processing and reprocessing teps to ultimate use and final disposition. All major sources of silver-containing emissions ere identified and their silver emissions into the atmosphere estimated. A regional breakdown f these sources and their emissions was also provided. The physical and chemical nature of e silver-containing emissions was delineated to the extent that information was available, d a methodology was recommended for updating the results of the study every 2 years.

59. King, J., ed.
1977. Symposium on fugitive emissions: measurement and control [Houston, Tex.]. 544 p. Research Corp. of New England, Wethersfield, Conn., and Industrial Environmental Research Lab., Research Triangle Park, N.C. [Available NTIS as PB-276 973/5ST.]

e proceedings are a compilation of technical papers prepared for presentation at the Second mposium on Fugitive Emissions, May 23-25, 1977, Houston, Tex. The papers discuss the cope and impact of fugitive emissions (nonpoint sources) and present techniques which have een used to measure these emissions. Fugitive emissions control technologies are also iscussed.

60. LeBlanc, F., G. Robitaille, and D. N. Rao.
1976. Ecophysiological responses of lichen transplants to air pollution in Canada. J. Hattori Bot. Lab. 40:27,40,268.

61. MSA Research Corp.
1974. Control of respirable dust in noncoal mines and ore processing mills. 104 p. Bureau of Mines, Washington, D.C. [Available NTIS as PB-240 646/OST.]

e objective of this manual is to provide guidance to the mining community for control of spirable dust based on currently available equipment and techniques. The survey of dust ntrol procedures included ores and minerals and different types of underground and open pit ning operations. Control procedures for dust in processing plants were surveyed. The types minerals and ores included in the survey were asbestos, bentonite, copper, gold, granite, on, lead, limestone, molybdenum, phosphate rock, potash, sand and gravel, talc, trona, and anium. More than 300 Bureau of Mines dust inspection reports were reviewed to establish ich work areas are most frequently cited as being above allowable dust concentration. The ltiplicity of types of ore and mining and processing practices dictates that mine management carefully select optimum dust control measures. This requires a determination of the free silica content of the ore since this factor sets the allowable respirable dust concentration and therefore the required efficiency of the dust control techniques.

262. National Research Council.
1971. Airborne asbestos. 61 p. Comm. on Biologic Effects of Atmospheric Pollutants, Washington, D.C. [Available NTIS as PB-198 581.]

The report (1) summarizes the major evidence of the pathogenicity of asbestos in man and animals, (2) summarizes the evidence of human nonoccupational exposure to asbestos, (3) evalua the evidence of a health risk associated with various degrees and types of exposure, (4) identifies sources of environmental contamination by asbestos, and (5) offers recommendations concerning the need for and feasibility of control measures.

263. Nelson, R.
1975. Meteorological dispersion potential in the Piceance Creek Basin. In Environment Oil Shale Symp. Proc. p. 223-237. Colo. Sch. Mines Quar. 70(4).

Turbulence in the valleys below the Piceance plateau is predominantly thermal. Therefore, inversion formation and dissipation within the valleys follow extremely predictable diurnal patterns. The depth of these inversions varies widely but seldom reaches more than 300 meters above the surface of the plateau regions and often is wholly contained within the valleys themselves. This formation and dissipation of inversions may lead to serious pollution problems if large pollutant releases are made within the valleys. In this case, fumigation may occur. Location of all plume release points upon the plateau regions will greatly minimiz the fumigation effects, if not alleviate it completely. Due to the enhanced mechanical turbulence a short distance above the surface of the plateau regions, plumes released from stacks 300 to 400 feet tall with a plume rise of about another 300 to 400 feet should very seldom produce a severe fumigation effect.

264. Peterson, W. L., and G. W. Douglas.
1977. Air quality monitoring with a lichen network: baseline data. Douglas Ecologica Consultants, Environ. Res. Mongr. 5, 79 p.

A network of 56 permanent plots, radiating from the periphery of the Syncrude lease, was established during the summer of 1976. This network will allow continuous quantitative monitoring of the lichen flora using photographic techniques. Since lichens are highly sensitive to air pollutants such as SO_2, they are capable of showing damage or reduced growth long before it is detectable in other vegetation. This "early warning system" may indicate that unnatural biological changes are beginning to take place in the ecosystem and appropriat action, if necessary, may then be taken to minimize further biological changes. It is recommended that partial resurveys of the grid network should be conducted annually during the first years of the Syncrude plant's operation.

265. Rodgers, S. J.
1974. Survey of past and present methods used to control respirable dust in noncoal mines and ore processing mills. 134 p. MSA Research Corp., Evans City, Penn. [Available NTIS as PB-240 662/7ST.]

A survey of methods used to control respirable dust in noncoal mines and ore processing mills was conducted. The survey covered information reported in mining journals, and U.S. Bureau o Mines circulars, dust inspection reports, on-site evaluation of dust control methods and systems, and contact with manufacturers of dust control equipment. Both surface and undergro mining operations were visited. Fifty mines and 51 processing plants were included in the survey. Dust control methods for 15 types of ores or mines were studied. The survey showed that the major reasons for overexposure to respirable dust were poor maintenance and housekee Poor maintenance practices were observed in the form of holes in ductwork, missing pieces of ductwork, worn shrouds, plugged spray nozzles, etc. Poor housekeeping practices were observe as piles of dust collected at transfer points and on rafters and beams. Other factors that result in overexposure included muck piles not being wetted down, poor design of dumps and chutes, dry drilling and undercutting, undersized ventilation equipment, and flow imbalances in exhaust systems.

266. Schultz, L., W. Bank, and G. Weems.
1973. Airborne asbestos fiber concentrations in asbestos mines and mills in the United States. Bureau of Mines, Washington, D.C. Rep. No. TPR-72, 19 p. [Available NTIS as PB-222 611/6.]

Personnel of the Bureau of Mines have conducted investigations in the principal asbestos mines and mills in the United States to determine the concentration of airborne asbestos fibers in the work place, and to establish the exposure of workers to such fibers. The surveys were conducted using the sampling and evaluation method recommended by the National Institute for Occupational Safety and Health. The method consists of collecting the airborne sample on filters and, after appropriate sample preparation, counting the fibers utilizing phase contrast microscopy. The results of the investigation show that fiber concentrations are low in the asbestos mines but high in the asbestos mills, ranging well above 5 fibers/ml of air based on a count of fibers greater than 5 micrometers in length.

267. Shannon, L. J., P. G. Gorman, and M. Retchel.
1971. Particulate pollutant system study. 343 p. Midwest Research Inst., Kansas City, Mo. [Available NTIS as PB-203-521.]

A program was conducted to quantify fine-particle emissions (0.01-2 microns) from particulate pollution sources. The primary objective was to use the best data currently available (1969-1970) on particle-size distributions of particulates from uncontrolled and controlled sources, fractional efficiency curves for specific control devices, and the degree of application of control equipment on specific sources to estimate the mass and number of fine particles emitted from particulate pollution sources. Secondary objectives were the assessment of (1) the applicability of standard sampling and particle sizing methods to the fine particle regime, and (2) the current understanding of the adverse effects of fine particulate pollutants. This report presents the results of this study.

268. Spangler, C. V.
1971. National inventory of sources and emissions: manganese - 1968. 70 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-220 620/9.]

The inventory of atmospheric emissions has been prepared to provide reliable information regarding the nature, magnitude, and extent of the emissions of manganese in the United States for the year 1968. Background information concerning the basic characteristics of the manganese industry has been assembled and included. Process descriptions are given, but they are brief, and are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant.

269. Stewart, I. M., R. E. Purscher, H. J. Humecki, and others.
1977. Asbestos fibers in discharges from selected mining and milling activities, part III. 50 p. McCrone Associates, Inc., Chicago, Ill. [Available NTIS as PB-264 288/2ST.]

The Office of Toxic Substances of the EPA has sponsored a nationwide survey to determine the impact of point and nonpoint sources on levels of waterborne asbestos. Part 1 of the final report presented the results of analyses of water from the ten regional cities. Part 2 of the final report presented the results of the analyses of water from natural sources and from point sources manufacturing asbestos products. Part 3 of the final report, contained herein, presents the results of the analyses of water from point sources associated with the mining and milling of potentially asbestos bearing rocks. The results of these analyses indicate that a variety of mineral ore types may have asbestos minerals associated with them and that these fibers are liberated into their effluents. In some instances, however, the final effluent has little impact on levels in the local surface water already have high asbostos contents.

270. Stosher, M. M.
1978. Ambient air quality in the AOSERP study area 1977. Alberta Soil and Environ. Res. Prog. Proj. ME 2.1, 74 p.

The monitoring network for ambient air quality in the AOSERP study area is described with particular reference to site location, instrumentation, measurement techniques, and data source The results of 1 to 3 years of data from 68 exposure cylinders and eight continuous monitoring stations are shown in tables and maps. Emission characteristics of the existing and proposed oil sands plants are described and related to processes for bitumen extraction and upgrading. Initial evaluation of data indicates that sulfur dioxide concentrations at ground level in background air are in the 0.001 ppm range. Annual average SO_2 concentrations at monitoring sites closer to the source range from 0.003 to 0.006 ppm. Monthly average levels of O_3 and NO_2 at a background station are approximately 0.045 ppm and 0.01 ppm respectively. Results of total sulfation measurements show no change in levels of total sulfur over the past 3 years. Initial results of total suspended particulates indicate very low levels except at Fort McMurra where levels greater than 100 $\mu g/m^3$ were recorded. The report recommends that a similiar document be prepared which would include all available data prior to the startup of the second oil sands plant.

271. Sullivan, R. J.
1969. Air pollution aspects of nickel and its compounds. 76 p. Environmental Systems Div., Litton Systems, Inc., Bethesda, Md. [Available NTIS as PT-188-070.]

Contains information on nickel's and nickel compound's effects on humans (dermatitis, respirat disorders, cancer of the respiratory tract); effects on animals; effects on plants; effects on materials; environmental air standards; natural occurrence; production sources (mines, metallu gical industry); product sources; other sources (asbestos, coal, fuel oil, incineration); environmental air concentration; abatement; economics; methods of analysis (sampling methods, quantitative methods [nickel particulates, nickel carbonyl]).

272. Vancura, P. D., and R. E. Chufo.
1978. Air monitor system at Grace Iron Mine - zeroing in on hazardous working areas. I and Mining J. 179(4):92-94.

273. Vandegrift, A. E., L. J. Shannon, P. G. Gorman, and others.
1971. Particulate pollution systems study, vol. I. Mass emissions. 376 p. Midwest Research Inst., Kansas City, Mo. [Available NTIS as PB-203 128.]

A program on particulate air pollution from stationary sources in the continental United States was conducted. The specific objective of the study was to identify, characterize, and, to the extent possible, quantify the particulate air pollution problem. Information was to be assembled and analyzed on the kind and magnitude of specific sources, and the status of curren control practices. The resultant information was to be used to identify deficiencies in current knowledge regarding the nature of important particulate pollution sources, and to provide requisite handbook data for the design and application of control devices. The results of the study are presented.

274. Vandegrift, A. E., L. J. Shannon, E. W. Lawless, and others.
1971. Particulate pollutant systems study, vol. III. Handbook of emission properties. 613 p. Midwest Research Inst., Kansas City, Mo. [Available NTIS as PB-203 522.]

A handbook is presented as part of the documentation for a study of particulate air pollution from stationary sources. The objective of the study was to identify, characterize, and quanti the particulate air pollution problem in the United States. The document delineates the kind and number of stationary particulate sources, the chemical and physical characteristics of both the particulates and carrier gas emitted by specific sources, and the status of current control practices. The first three chapters of the handbook present general background informa tion pertaining to source emission factors and emission rates, effluent characteristics, and control technology. The next chapter discusses some of the more important chemical and physica properties of particulates and carrier gas emitted by industrial sources. The remaining chapte present discussions of the major industrial sources of particulate pollutants.

75. Walmsley, J. L., and D. L. Bagg.
1977. Calculations of annual averaged sulphur dioxide concentrations at ground level. Alberta Oil Sand Environ. Res. Prog. Proj. ME 4.1, 40 p.

he Climatological Dispersion Model and the input data required for calculation of annual veraged values of sulfur dioxide concentrations at ground level are described. The most mportant meteorological input to the model is the long-term joint frequency distribution of inds in the vicinity of the sources of atmospheric pollution. These data are computed with he help of statistics of wind correlations between Fort McMurray and Mildred Lake, Alberta. umerical experiments are performed with and without parameterized pollutant removal processes. he effect of incorporating terrain in the model is examined. Experiments comparing concentra-ions due to existing sources with those due to existing and future sources are performed. esults are also compared with observational data from pollution monitors and snowpack sampling. stimates are made of sulfur loading due to dry deposition.

F. Effects on Water

Citations in section F are subdivided into three categories: (1) water quality, (2) acid mine drainage, and (3) effects on ecology and biota. Citations included under water quality are those citations which deal with general water pollution, control, and with impacts of surface mining on hydrology and consumptive water use. Subsection 2 separates acid mine drainage as a special problem. Numerous citations exist describing the acid mine drainage problem. However, most of these describe the problem as it exists in coal mining in the East (see bibliographies 4, 10, 49, and 60). Acid mine drainage is also a major problem associated with heavy metals and some coal mining in the West (see citations 352, 359, and 364). Citation included in this section deal with solutions to the problem of acid mine drainage, which can be applied in both eastern and western mining. Citations in subsection 3 include those which deal primarily with the effects of mine water pollution on the ecology and biology of aquatic ecosystems. (See also "fish" under "fauna" in the index.)

1. WATER QUALITY AND HYDROLOGICAL ASPECTS

276. Battelle Memorial Institute.
1975. Water pollution abatement technology capabilities, ore mining and milling. 2603 p. Battelle Memorial Inst., Richland, Wash. [Available NTIS as PB-251 437/OST.]

Technologies are examined for 38 industry segments to meet water pollution abatement requirements of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500). Levels of pollution abatement which are reviewed include those promulgated by the U.S. Environmental Protection Agency for 1977 (PBCTCA or best practicable control technology currently available) and for 1983 (BATEA or best available technology economically achievable). Capital and operati and maintenance costs are presented in 1973 dollars. Performance is stated in terms of resulti effluents.

277. Battelle Memorial Institute.
1971. Inorganic fertilizer and phosphate mining--water pollution and control. 228 p. Battelle Memorial Inst., Richland, Wash. [Available NTIS as PB-206 154/7ST.]

A state-of-the-art survey was made of the water pollution problems that result from the production of inorganic fertilizers and phosphate rock. Information required to complete the study was obtained through an extensive literature search, questionnaires sent to the major fertiliz producers, and visits to selected production plants. Ninety-eight plants representing 33 different companies were surveyed. Production figures since 1940 and estimates of production through 1980 were accumulated for phosphate rock and the major fertilizer products. The specific production operations which are the principal generators of contaminated waste waters were identified, and the waste water volumes and compositions for each operation were determin wherever possible. The capability of current technology to treat and control the contaminated waste waters generated by the fertilizer industry was evaluated. Problem areas where addition research and development effort is needed to provide adequate control of waste water discharge were identified.

278. Bauer, S. B.
1974. Heavy metals in lakes of the Coeur d'Alene River, Idaho. Master's thesis. Univ. Idaho, Moscow. 66 p.

Heavy metal concentrations were measured in the water, sediments, and fish of nine small lakes located along the main stem of the Coeur d'Alene River. Mining wastes have been discharged into this drainage since the 1890's. Concentrations of dissolved metals were low in the lakes and did not differ significantly from lake to lake. Zn, Cu, Cd, Pb, Cs, and Sb have accumulat in lake sediments. The concentrations of these metals varied in sediments from lake to lake, and within each lake concentrations were highest at stations close to the river.

279. Bogner, J. E., and D. O. Johnson.
1977. Environmental control technology program studies at Argonne National Laboratory: surface mine effluents. 10 p. Argonne National Lab., Ill. [Available NTIS as CONF-7710101-4.]

The chemical quality of surface waters in areas characterized by coal strip mining is the result of both local and regional factors, including composition of coal, overburden, and underclay; mobility of selected chemical constituents in rocks, sediments, and mine soils; activity of chemoautotrophic bacteria; mining and reclamation methods and equipment; density of mining operations in a given watershed; seasonal fluctuations in regional stream discharges; and control technologies implemented to treat mine effluents. The major problems associated with mine effluents in the eastern region are acid mine drainage, generated by the oxidation and subsequent hydrolysis of iron disulfide minerals, and high concentrations of dissolved metals and suspended solids. Control technologies commonly utilized to ameliorate these problems include (1) the addition of alkaline reagents such as hydrated lime, soda ash, or sodium hydroxide to neutralize the acids and promote the precipitation of dissolved metals; and (2) the construction of settling ponds to promote the sedimentation of suspended solids.

280. Bolter, E., and N. H. Tibbs.
1970. Impact of lead-zinc mining on the quality and ecology of surface waters in southeast Missouri. 84 p. Water Resour. Res. Center, Rolla, Mo. [Available NTIS as PB-1974 531.]

The background concentrations were determined for copper, lead, and zinc in the streams of the Viburnum Trend or New Lead Belt of Southeast Missouri. Analytical methods were developed for atomic absorption spectroscopy. These methods initially consisted of coextraction of copper, lead, and zinc using the APDC/MIBK system, and finally of extraction of copper by APDC/MIBK and direct analysis of lead and zinc using the newly developed "sampling boat" technique. The data obtained from these analyses were arranged in histograms and critically analyzed. The background concentrations were established to be 4 to 6 ppb for all three elements. Methods are presented for identifying both short term and long term contamination by using the data distributions. The data distributions were not useful for geochemical prospecting under the studied geological conditions.

281. Bolter, E., and N. H. Tibbs.
1971. Water geochemistry of mining and milling retention ponds in the New Lead Belt of Southeast Missouri. 40 p. Water Resour. Res. Center, Rolla, Mo. [Available NTIS as PB-204 889.]

The heavy metal content and other geochemical data of the mine and mill waters of two mining operations in the "New Lead Belt" of southeastern Missouri were determined and the efficiency of retention ponds in reducing high metal concentrations was investigated. The mine waters from two mines of this mining district, which is the largest lead producer in the world, showed a heavy metal content of less than 6 ppb copper, 66 ppb lead, and 37 ppb zinc. The heavy metal content from the mill effluents was reduced to values similar to mine water, when the pond sizes were large enough. The concentrations of calcium, magnesium, sodium, and potassium, and pH allow the tracing of mine water in the streams. The retention ponds are not entirely efficient in preventing transport of metal rich rockflower in the streams.

282. Brown, A., and others.
1977. Water management in oil shale mining, vol. II, appendices. 318 p. Golder Associates, Inc., Kirkland, Wash. [Available NTIS as PB-276 086/6WN.]

283. Colorado State University.
1971. Water pollution potential of spent oil shale residues. U.S. Environ. Protect. Agency, EPA Document-Grant WO. 14030 EDB, 116 p. Washington, D.C.

284. Dalton, Dalton, Little, Newport.
1977. Water pollution from mining activities. 72 p. Sixth Dist. Counc. of Government, Rapid City, S.Dak.

285. Dames and Moore.
1976. Final report: water quality data at selected active placer mines in Alaska. 49 p. Calspan Corporation, Buffalo, N.Y.

Current Environmental Protection Agency (EPA) effluent criteria pertaining to the placer mining industry have been protested by the Alaska Placer Mining Committee and the Alaska Miners Association as being impractical. Subsequent to these protests, the EPA has initiated a review of the current criteria and contracted Calspan Corporation to collect data from placer mining operations in Alaska. Calspan, in turn, subcontracted Dames and Moore's Fairbank office to conduct field surveys in August 1976. The information generated by this field work, and data presented in this report are based on Calspan's requirements for data collection.

286. Environmental Protection Agency.
1975. Water quality impacts of uranium mining and milling activities. 188 p. Environ. Protect. Agency, Region IV, Dallas, Tex., Report No. EPA 1906/9-75/002.

Ground water in the study area is affected by mining and waste disposal associated with mining and milling. Contamination appears in close proximity to the mining and milling centers with the exception of more widespread selenium contamination of shallow ground water adjacent to the United Nuclear-Homestake Partners Mill. Contamination of municipally operated water supplies in the study area is not evident. Potable supplies derived from mine water at four industrial sites exceed acceptable limits for selenium in drinking water. Three such systems exceed limits for Radium 226. Recommendations developed are designed to assist the state in future regulation of uranium mining and milling for the purpose of safeguarding public health and insuring future environmental quality.

287. Environmental Protection Agency.
1971. Evaluation of the impact of the Mines Development, Inc. mill on water quality conditions in the Cheyenne River. 51 p. Environ. Protect. Agency, Reg. VIII, Denver, Colo. [Available NTIS as PB-255 270/IST.]

An intensive water quality study of the Cheyenne River and the tributary stream, Cottonwood Creek, in the environs of the Mines Development mill located at Edgemont, S.Dak., was conducted The objectives of the study were to determine and evaluate: (1) water quality conditions in Cottonwood Creek and the Cheyenne River during a period of dry weather flow; (2) chemical and radioactivity loadings (mas/day) on Cottonwood Creek and the Cheyenne River as the result of seepage from mill ponds; and (3) radioactivity levels in the water, biota, and bottom sediment of Angostura Reservoir.

288. Environmental Protection Agency.
1972. Impact of the Schwartzwalder Mine on the water quality of Ralston Creek, Ralston Reservoir, and Upper Long Lake. 40 p. Tech. Invest. Br., Environ. Protect. Agency, Denver, Colo. [Available NTIS as PB-255 604/IST.]

Considering the magnitude of radioactivity concentrations in Ralston Creek and use of the stream as a primary water source for two water supply reservoirs--Ralston Reservoir and Upper Long Lake, EPA Region VIII initiated a limiting monitoring effort to supplement the state water board program. This monitoring activity extended over the period of May through Septembe 1972. Emphasis was placed on eliminating critical data voids; that is, radioactivity concentrations in the waters of Ralston Reservoir and Upper Long Lake. In addition to the grab water samples collected from these impoundments, sample collection included the mine effluent, water and bottom sediment samples from the two impoundments and Long Lake ditch, and bottom sediment samples from the two impoundments.

289. Environmental Protection Agency.
1975. Development document for interim final effluent limitations guidelines and new source performance standards for the minerals for the construction industry, vol. I. Mineral mining and processing industry. 284 p. Effluent Guidelines Div., Environ. Protect. Agency, Washington, D.C. [Available NTIS as PB-274 593/3ST.]

This document presents the findings of an extensive study of selected minerals in the Minerals for the Construction Industry segment of the mineral mining industry for the purpose of developing effluent limitations guidelines for existing point sources and standards of performance and pretreatment standards for new sources, to implement sections 301, 304, 306 and 307 of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1551, 1314, and 1315, 86 Stat. 816 et. seq.) (the "Act"). Based on the application of best practicable technology currently available, six of the nine production subcategories (comprising 15 minerals) under study can be operated with no discharge of process generated waste water pollutants to navigable waters. With the best available technology economically achievable, eight of the nine production subcategories can be operated with no discharge of process generated waste water pollutants to navigable waters. No discharge of process generated waste water pollutants to navigable waters is achievable as a new source performance standard for all production subcategories except mica, wet benefication process with ceramic grade clay as a byproduct. Supporting data and rationale for development of the proposed effluent limitations guidelines and standards of performance are contained in this report.

290. Gale, W. F., T. V. Jacobsen, and K. M. Smith.
1976. Iron, and its role in a river polluted by mine effluents. Proc. Penn. Acad. Sci. 50(2):182-195.

291. Garinger, L. E.
1977. The regulation of water use in placer mining in the Yukon Territory. In Second Annu. Convention, Alaska Miners Assoc., Proc., Anchorage. p. 14-16.

Experience in the Yukon Territory has been that working closely and communicating with the placer miners and the environmental agency has resulted in a realistic environmental approach. Fish do exist in conjunction with controlled placer mining. Fish have reestablished their population in mined out streams. Some mines in permafrost regions must have unrestricted usage of water in order to exist economically. Unsophisticated settling/filtration facilities can be provided to minimize silt loading on the streams.

292. Germanov, A. I., S. G. Batulin, G. A. Volkov, and others.
1958. Some regularities of uranium distribution in underground waters. Proc., 2d U.N. Int. Conf., Peaceful Uses Atomic Energy, Geneva 2:161-177.

293. Gries, J. P., and P. H. Rahn.
1974. The geochemistry of certain mine and spring waters, western South Dakota. 40 p. S.Dak. Sch. Mines Technol., Rapid City. [Available NTIS as PB-239 829/5ST.]

Fourteen inactive or abandoned gold-silver, lead-silver, or lead-zinc mines were located in the Northern Black Hills which discharge water from their portals or shaft collars. Some discharge fairly evenly throughout the year; some show high seasonal variation; and some drain only during the spring and early summer months. Determinates made include volume of discharge, water temperature, hydrogen ion concentration (pH), specific conductance, and total iron. Where significant discharge entered directly into a stream, measurements were made of the stream water above and below the point of entry of the mine drainage. The only mine workings to show discharges with low pH and high total iron were those with generally very small flow (less than 5 gal/min) from workings developed in highly pyritized porphyry or schist. Large discharges, regardless of rock type, were potable as far as pH, iron, and total dissolved solids were concerned. Effects of these discharges upon streams large enough to support aquatic life were negligible.

294. Grove, D. B., R. L. Miller, L. F. Konikow, and others.
1979. Hexavalent chromium in ground and surface waters near Telluride, Colo. 16 p. U.S. Geol. Surv. open file rep., Jan. 1979.

Data showing the results of 39 ground-water and 30 surface-water samples analyzed for hexavale chromium are presented. Most samples were taken within the Telluride, Colo., city limits during October 1978. Sixty-three percent of the ground-water samples contained more than 50 micrograms per liter of hexavalent chromium. Twenty-one percent of the surface-water samples contained more than 50 micrograms per liter of hexavalent chromium. Ground-water concentratio range from 0 to 2,700 per liter and surface-water concentrations range from 0 to 160 microgram per liter.

295. Hallowell, J. B., J. F. Shea, G. R. Smithson, Jr., and others.
1973. Water-pollution control in the primary nonferrous-metals industry, vol. I. Copper, zinc, and lead industries. 173 p. Battelle Columbus Labs., Ohio. [Availab NTIS as PB-229 466/8ST.]

The contents of the final reports (two volumes) include: the identification of process steps using water and/or generating wastewater; the amounts of water used for various purposes; recirculation rates; amounts of wastewaters; specific or characteristic substances in wastewaters; the prevalence of wastewater treatment practice, methods, and costs; current treatment problems; and plans for future practices of recirculation of wastewater treatment. Metals included are copper, lead, zinc, and associated byproducts (arsenic, cadmium, silver, gold, selenium, tellurium, sulfuric acid, salts, and compounds), mercury (primary), gold and silver, aluminum, molybdenum, and tungsten. The information includes detailed processing descriptions and flowsheets, tabulations of quantities of water, discharge water quantities and analyses, and water treatment costs.

296. Hallowell, J. B., J. F. Shea, G. R. Smithson, Jr., and others.
1973. Water-pollution control in the primary nonferrous-metals industry, vol. II. Aluminum, mercury, gold, silver, molybdenum, and tungsten. 116 p. Battelle Columbu Labs., Ohio. [Available NTIS as PB-229 467/6ST.]

The treatment needs of the aluminum industry relate to common types of industrial wastewater such as cooling tower blowdown and neutralization products, and the specialized need to remove or recover fluoride ion components from fume scrubbers at smelters. The primary mercury industry, by virtue of a current air pollution control problem, may require increased measures of water pollution control associated with air emission control equipment or new processing methods. The primary molybdenum industry has taken or is designing effective methods of water pollution control ranging from isolated water systems to changes in flotation reagent concentra tions. Plants processing refractory metal concentrates to end products generally are associat with municipal water systems and show high materials recoveries with concurrent close control and careful segregation of wastewater streams. Neutralization with filtration of acid wastes is a common practice of the plants surveyed. The small amount of information available for the primary gold and silver industries shows greatly differing practices, ranging from zero discharge in arid climates to problems with mercury and cyanide contents in wastewaters.

297. Hardley, M. G., and others.
1974. Water resources problems and solutions associated with the New Lead Belt of southeastern Missouri. In Water resources problems related to mining. R. F. Hadley and D. T. Snow, eds. Am. Water Resour. Assoc., Minneapolis, Minn., Proc. 18:109-122.

298. Harriss, R. C., and others.
1972. Effect of pollution on the marine environment: a case study. In Coastal Zone Pollution Management Symposium Proc. p. 249-264. B. L. Edge, ed. [Charleston, S.C., Feb. 21-22.]

299. Havlik, B., J. Grafova, and B. Nycova.
1968. Radium liberation from uranium ore processing mill waste solids and uranium rocks into surface streams. (I) The effect of different pH of surface waters. Health Phys. 14:417-422.

300. Hird, J. M.
1971. Control of artesian ground water in strip mining phosphate ores, eastern North Carolina. Am. Inst. Mining, Metallurgical, and Petroleum Eng., Soc. Mining Eng., Trans. 250(2):149-156.

Control of artesian ground water has played an important role in the development of Texas Gulf Sulphur's phosphate mining venture in eastern North Carolina. To facilitate dry mining methods, 0 mgd of fresh water is pumped through wells from a limestone aquifer underlying the uniform flat-lying ore section. High volume pumping has lowered water levels in water wells over a large area in the Coastal Plain without detrimental effects on water quality in the aquifer. An intricate observation well system is monitored regularly over the wide area of pumping effect to ensure that gradient reversals have not caused slat water encroachment.

301. Horton, J. O.
1974. Water for energy. Am. Mining Congr., Washington, D.C.

Identifies supply problems in upper Colorado River Basin, Northern Great Plains, and upper Missouri River Basins.

302. International Minerals and Chemical Corporation.
1978. Water in the bank - an innovative recharge approach. 12 p. Int. Min. and Chem. Corp., Lakeland, Fla.

The International Minerals and Chemical Corporation in conjunction with the southwest Florida Water Management District, the Floridan Department of Pollution Control, and the U.S. Geological Survey has extensively researched the problem of diminishing water supply in Florida. The research resulted in an innovative solution: recharge wells. This pamphlet presents the basics of the problem and the solution.

303. Jarrett, B. M., and R. G. Kirby.
1978. Development document for the effluent limitations and guidelines for the ore mining and dressing point source category, vol. I. 424 p. Effluent Guidelines Div., Environ. Protect. Agency, Washington, D.C. [Available NTIS as PB-286 520/2ST.]

To establish effluent limitation guidelines and standards of performance, the ore mining and dressing industry was divided into 41 separate categories and subcategories for which separate limitations were recommended. This report deals with the entire metal-ore mining and dressing industry and examines the industry by 10 major categories: iron ore; copper ore; lead and zinc ores; gold ore; silver ore; bauxite ore; ferroally-metal ores; mercury ores; uranium, radium and vanadium ores; and metal ores, not elsewhere classified (ores of antimony, beryllium, platinum, rare earth, tin, titanium, and zirconium). The subcategorization of the ore categories is based primarily upon ore mineralogy and processing or extraction methods employed; however, other factors (such as size, climate or location, and method of mining) are used in some instances. With the best available technology economically achievable, facilities in 21 of the 41 subcategories can be operated with no discharge of process wastewater to navigable waters. No discharge of process wastewater is also achievable as a new source performance standard for facilities in 21 of the 41 subcategories.

04. Jennett, J. C., and M. G. Hardie.
1974. Impact of lead mining and milling operations on stream water quality in southeast Missouri. In Proc., 2d Annu. Trace Contam. Conf. [Pacific Grove, Calif.]. p. 172-182. [Available NTIS as TID-4500-R62.]

The investigations summarized were performed in order to: (1) evaluate the effects which the development of the world's largest lead mining district, known as the New Lead Belt or Viburnum

Trend of southeast Missouri, would produce on the quality of the streams draining the Clark National Forest area surrounding these operations; (2) to evaluate the role which these water systems play in the transport of heavy metals through and out of the forest ecosystem; and (3) where possible, to explore techniques for improving the water quality of the region. Data in tabular and graphical form are appended.

305. Johnston, R. S., and R. W. Brown.
1979. Hydrologic aspects related to the management of alpine lands. In Special management needs of alpine ecosystems. p. 66-75. D. A. Johnson, ed. Soc. Range Manage, Range Sci. Series No. 5.

306. Kaufmann, R. F., and J. D. Bliss.
1977. Effects of phosphate mineralization and the phosphate industry on Radium-226 in ground water of central Florida. 27 p. Office of Radiation Programs, Las Vegas, Nev. [Available NTIS as PB-274 116/3ST.]

Principal U.S. phosphate production is from central Florida where mining, processing, and waste disposal practices intimately associate the industry with water resources. Available Radium-226 data from 1966 and from 1973-1976 were statistically analyzed to characterize radium in the water table, Upper Floridan, and Lower Floridan aquifers. Mined and unmined mineralized areas and nonmineralized areas in the primary study area in Polk, Hardee, Hillsborough, Manatee, and De Soto counties were studied. Log-normal probability plots and non-parametric statistical tests (Mann-Whitney, Kruskal-Wallis, Kolmogorov-Smirnov, simultaneous multiple comparison) were used to analyze for central tendency, variance, and significant difference as functions of time, depth, and location.

307. Kaufmann, R. F., G. G. Eadie, C. R. Russell, and others.
1977. Effects of uranium mining and milling on ground water in the Grants Mineral Belt, New Mexico. 14 p. Office of Radiation Programs, Las Vegas, Nev. [Available NTIS as PB-262 819/6ST.]

Ground-water contamination from uranium mining and milling results from the infiltration of mine, mill, and nonexchange plant effluents containing elevated concentrations of radium, selenium, and nitrate. Available data indicate that radium concentrations are generally about several picocuries/liter (pCi/l); 100 to 150 pCi/l appear in the effluents of operating mines. The discharge of such highly contaminated mine effluents to streams and seepage from tailings ponds creates a long-lived source of ground-water contamination. Seepage of mill tailings at two active mills ranges from 126,000 to 491,000 m^3/yr and, to date, has contributed an estimate 2,400 curies of uranium, radium, and thorium to the ground-water reservoir. Radium, selenium, nitrate, and to a lesser extent, uranium, are of most value as indicators of ground-water contamination.

308. Kaufmann, R. F., G. G. Eadie, C. R. Russell, and others.
1975. Summary of ground-water quality impacts of uranium mining and milling in the Grants Mineral Belt, New Mexico. 81 p. Office of Radiation Programs, Las Vegas, Nev. [Available NTIS as PB-247 282/7ST.]

Ground-water contamination from uranium mining and milling results from the infiltration of radium-bearing mine, mill, and ion-exchange plant effluents. Radium, selenium, and nitrate were of most value as indicators of contamination. In recent years, mining has increased radium in mine effluents from several picocuries/liter (pCi/l) or less, to 100-150 pCi/l. The shallow aquifer in use in the vicinity of one mill was grossly contaminated with selenium, attributable to the mill tailings. Seepage from two other mill tailings ponds averages 67,400, liters per year and, to date, has contributed an estimated 1.1 curies of radium to ground water. At one of these an injection well was used to dispose of over 3,400,000,000 liters of waste from 1960-1973. The wastes have not been properly monitored and have apparently migrated to more shallow potable aquifers. No adverse impacts on municipal water quality in Paguate, Bluewater, Grants, Milan, and Gallup were observed.

09. Lawrence, J., and H. W. Zimmermann.
1977. Asbestos in water: mining and processing effluent treatment. Water Pollution Contr. Fed. J. 49(1):156-160.

10. Magorian, T. R., K. G. Wood, J. G. Michalovic, and others.
1974. Water pollution by thallium and related metals. 196 p. Calspan Corp., Buffalo, N.Y. [Available NTIS as PB-253 333/9ST.]

sampling program was planned and carried out to elucidate the extent of movement and concentraion of thallium and related metals in physical and biological compartments of the aquatic nvironment. During this project, Calspan personnel sampled smelter and mill wastewater utfalls, receiving water, slag heaps, tailings ponds and streams, and coal-burning facility ly ash dumps. The amount of heavy metals in sediment is greater at any given time than that issolved in water, and hence floodwater erosion of particulate matter presents a hazard. Up o 17 percent lead, 0.1 percent cadmium, and 5 ppm thallium were found in sediments of streams sed for irrigation and drinking water below copper and zinc extractive industries in high unoff regions. Ground-water infiltration in the Northwest and Ozarks provides mine drainage ater which is used in mills and/or concentrators. This volume of water transports toxic astes into naturally erosive bottom sediments, thereby contaminating the food chain. Heavy etal concentrations in water are higher in the fall at low water following benthic accumulaions during the growing season. Metal pickup by algae was measured in the laboratory. rocedures for detecting and measuring the amount of thallium by atomic absorption in the resence of concentrations of chloride and other ions were developed.

11. Miller, J. A., G. H. Hughes, and R. W. Hull.
1978. Impact of potential phosphate mining on the hydrology of Osceola National Forest, Florida. 169 p. U.S. Geol. Surv., Tallahassee, Fla. [Available NTIS as PB-278 853/7ST.]

otentially exploitable phosphate deposits underlie part of Osceola National Forest. Hydrologic onditions in the forest are comparable with those in nearby Hamilton County, where phosphate ining and processing have been ongoing since 1965. Given similarity of operations, hydrologic ffects of mining in the forest are predicted. Flow of stream(s) receiving phosphate industry ffluent would increase somewhat during mining, but stream quality would not be greatly affected. ocal changes in the configuration of the water table and the quality of water in the surficial quifer will occur. Lowering of the potentiometric surface of the Floridan aquifer because of roposed pumpage would be less than 5 feet at nearby communities. Floridan aquifer water uality would be appreciably changed only if plant effluent were discharged into streams which echarge the Floridan through sinkholes. The most significant hydrologic effects would occur t the time of active mining; long-term effects would be less significant.

12. Mink, L. L., A. T. Wallace, and R. E. Williams.
1971. Effects of industrial and domestic effluents on the water quality of the Coeur d'Alene River Basin. Idaho Bur. Mines and Geol., Pamphlet 49, 94 p. Moscow, Idaho.

13. Mohammad, O. M. J.
1977. Evaluation of the present and potential impacts of open pit phosphate mining on ground-water resource systems in southeastern Idaho phosphate field. Ph.D. diss. Univ. Idaho, Moscow. 179 p. [Diss. Abstr. Int. 38/03-B:1109.]

14. Morgan, J. M., Jr.
1959. A stream survey in the uranium mining and milling area of the Colorado Plateau. 354 p. The Johns Hopkins Univ., Baltimore, Md.

15. National Enforcement Investigations Center.
1975. Impacts of uranium mining and milling on surface and potable waters in the Grants Mineral Belt, New Mexico. 85 p. Natl. Enforcement Invest. Cent., Denver, Colo. [Available NTIS as PB-255 583/7ST.]

On September 25, 1974, NMEIA requested EPA Region VI to conduct a survey of water-pollution sources and surface and ground-water quality in the Grants Mineral Belt. Studies conducted from February 24 to March 6, 1975, included industrial waste source evaluation, potable water sampling, and limited stream surveys by National Enforcement Investigations Center (NEIC) and ground-water evaluations by ORP-LVF. This report presents the findings of analyses of surface water streams, potable water supplies, and industrial discharges. Appendix C contains raw data for all samples collected during the survey and analyzed by NEIC. The NEIC analysis, when combined with the ORP-LVF report, will present an overall study of water quality in the Grants Mineral Belt.

316. National Field Investigations Center.
1973. Reconnaissance study of radiochemical pollution from phosphate rock mining and milling. 106 p. Natl. Field Invest. Cent., Denver, Colo. [Available NTIS as PT-241 242/7ST.]

A reconnaissance study of the phosphate mining and milling industry was necessary to investiga the magnitude of radiochemical pollution to receiving waters. This report describes the findings of the study and other related problems associated with processing of phosphate fertilizers, such as air pollution, ground-water contamination, possible deleterious consequen of fertilizer use, effects on other receiving water uses, including shellfish and drinking water supplies, and the use of byproduct material in the construction industry. Throughout the report a comparison has been made of reconnaissance sampling results with promulgated radiochemical standards and guidelines. Pollution control and analysis and water quality data are also discussed.

317. National Limestone Institute, Inc.
1977. Limestone purifies water. 33 p. Natl. Limestone Inst., Inc., Fairfax, Va.

A review of the scientific and technical materials available reveals that rainfall runoff involving limestone operations is nondeleterious to water and is, in fact, beneficial to the aquatic environment. This fact makes limestone different from the mining process for any other mineral substance, including coal, metallic ores, granite, traprock, clay, and sand or gravel. In the face of deteriorating water quality, due in part to acidic rainfall and coal mine acid drainage, limestone is a beneficial additive to water.

318. Norbeck, P. N., L. L. Mink, and R. E. Williams.
1974. Ground-water leaching of jib tailing deposits in the Coeur d'Alene district of northern Idaho. In Water resources problems related to mining. p. 149-157. Am. Water Resour. Assoc., Minneapolis, Proc. 18, 236 p.

319. Probstein, R. F., and H. Gold.
1978. Water in synthetic fuel production: the technology and the alternatives. 296 p. The MIT Press, Cambridge, Mass.

A comprehensive text on water use, water consumption, and requirements for synthetic fuel production, including water uses and needs in mining. Technology and alternatives are discuss

320. Proctor, P. D., and B. Sinha.
1978. Heavy metal mobilization, transportation and fixation in the Fredericktown Co-Ni-Cd-Cu-Zn-Pb providence to Lake Wappapello, Missouri as related to surface waters, stream sediments and stream algae. 46 p. Missouri Water Resour. Res. Cent., Rolla. [Available NTIS as PB-282 371/4ST.]

In a unique geologic occurrence and setting in the central United States, cobalt, nickel, cadmium, copper, zinc, and lead ores have been mined and milled from the Fredericktown metalliferous province in southeast Missouri. Major objectives of this study were to determine the heavy metal content in the river waters, stream sediments, and stream algae in drainage areas affected by mining and milling operations in the Fredericktown area. A second major objective was to compare the metal contents of these three media with the same media in an area not known to contain significantly anomalous contents of heavy metals, yet in a Precambri rock terrain. A third objective is to compare the heavy metal contents in stream sediments, tream waters, and algae near the mouth of the St. Francis River where it enters Lake Wappapello ith areas of Stouts Creek and Fredericktown to the north to determine the fate of heavy etals in this more stable water environment.

21. Public Health Service.
1970. Radium monitoring network. Div. of Water Supply and Pollution Contr., Public Health Serv., Denver, Colo., Data Release Number 1-16, 32 p. [Available NTIS as PB-260 231/6ST.]

he 16th data release report provides Radium-226 and uranium sampling results that supplement ata from 15 previous reports dated October 1962 through July 1969. The tabular data indicate vidence of radium and uranium below recommended concentration levels from analysis of composite ater samples at stations of the Radium Monitoring Network of the Colorado River Basin Water uality Control Project. The network is a surveillance system consisting of continuous surface ater sampling at 27 locations throughout the basin. It assays the radiological content of iver water over the entire basin.

22. Public Health Service.
1963. Shiprock, New Mexico uranium mill accident of August 22, 1960. 66 p. Div. of Water Supply and Pollution Control, Public Health Serv., Denver, Colo. [Available NTIS as PB-260 237/3ST.]

he conduct of field investigations of this incident, in which a raffinate waste liquor holding ond wall ruptured, is reviewed along with its effect on downstream water users. Chemical nd physical data for river water samples leave little doubt that the mill wastes reached the an Juan River in considerable quantity by the following day. The need for stringent prevention easures is discussed.

23. Public Health Service.
1961. Stream surveys in vicinity of uranium mills. III. Area of Uravan, Slick Rock, and Gateway, Colorado-August 1960. 38 p. Div. of Water Supply and Pollution Control, Public Health Serv., Denver, Colo. [Available NTIS as PB-260 289/4ST.]

his is a report of one of three short-term field studies carried out in the vicinity of ranium processing mills in western Colorado and eastern Utah during August 1960. These tudies were the initial undertaking of the Colorado River Basin Water Quality Control Project nd were made for the purpose of determining the pollutional constituents contained in uranium ill discharges and the effects of these discharges on receiving waters in certain specific reas of the Colorado River Basin. The results of the other studies are contained in reports f the Colorado River Basin Project.

24. Public Health Service.
1962. Stream surveys in vicinity of uranium mills. IV. Area of Shiprock, New Mexico - November 1960. 33 p. Div. of Water Supply and Pollution Control, Public Health Serv., Denver, Colo. [Available NTIS as PB-260 290/2ST.]

e findings of an 8-day field survey of stream conditions in the San Juan River below Shiprock, w Mexico, are reported. The survey followed a brief investigation in connection with the cidental release of a relatively large volume of highly toxic acid waste from the Kerr-McGee l Industries uranium mill at Shiprock in August 1960. Residual effects and long-term conditions are evaluated. Water quality conditions were evaluated on the basis of radiological, emical, and biological data collected in the study area.

25. Purtyman, W. D., C. L. Wienke, and D. R. Dreesen.
1977. Geology and hydrology in the vicinity of the inactive uranium mill tailings pile, Ambrosia Lake, New Mexico. 36 p. Los Alamos Sci. Lab., N.Mex. [Available NTIS as LA-6839-MS.]

326. Rouse, J. V.
1974. Radiochemical pollution from phosphate rock mining and milling. In Water resour problems related to mining. p. 65-71. R. F. Hadley and D. T. Snow, eds. Am. Water Resour. Assoc., Minneapolis, Minn., Proc. 18, 236 p.

327. Ryan, R. K., and P. G. Alfredson.
1976. Liquid wastes from mining and milling of uranium ores: a laboratory study of treatment methods. 43 p. Aust. Atomic Energy Comm. Res. Establishment, Lucas Heights. [Available NTIS as AAEC/E-394.]

328. Ryck, F., Jr., and J. R. Whitley.
1974. Pollution abatement in the lead mining district of Missouri. Purdue Univ. Eng. Bull. Eng. Ext. Serv. 145, p. 857-863.

This report documents biological conditions in three streams prior to and after the start of lead mining and milling, and evaluates the effectiveness of mill effluent recycling and stream channel modification as pollution abatement techniques.

329. Ryon, A. D., F. J. Hurt, and F. G. Seeley.
1977. Nitric acid leaching of radium and other significant radionuclides from uranium ores and tailings. Oak Ridge Natl. Lab., Rep. ORNL/TM-5944, 37 p. Oak Ridge, Tenn.

330. Sceva, J. E.
1973. Water quality considerations for the metal mining industry in the Pacific Northw 83 p. U.S. Environ. Protect. Agency, Seattle, Wash. [Available NTIS as PB-226-995.]

The paper includes sections on water quality considerations at active mines (including recomme practices); water quality considerations at abandoned mines (including recommended practices for closing a mine); and guidelines for construction of mine roads.

331. Scott, R. L., and R. M. Hays.
1975. Inactive and abandoned underground mines. Water pollution prevention and contro 322 p. Michael Baker, Jr., Inc., Beaver, Penn. [Available NTIS as PB-258 263/3ST.]

Underground mining operations across the United States produce a number of environmental problems. The foremost of these environmental concerns is acid discharges from inactive and abandoned underground mines that deteriorate streams, lakes, and impoundments. Waters affecte by mine drainage are altered both chemically and physically. This report discusses in Part I the chemistry and geographic extent of mine drainage pollution in the United States from inactive and abandoned underground mines; underground mining methods; and the classification of mine drainage control techniques. Control technology was developed mainly in the coal fields of the Eastern United States and may not be always applicable to other regions and other mineral mining. Available at-source mine drainage pollution prevention and control techniques are described and evaluated in Part II of the report and consist of five major categories: (1) water infiltration control; (2) mine sealing; (3) mining techniques; (4) water handling; and (5) discharge quality control. This existing technology is related to appropriate cost data and practical implementation by means of examples.

332. U.S. Environmental Protection Agency.
1975. Water quality impacts of uranium mining and milling activities in the Grants Mineral Belt, New Mexico. U.S. Environ. Protect. Agency, Dallas, EPA/906/9-75/002, 188 p. [Available NTIS as PB-251/470/1WN.]

333. U.S. Geological Survey.
1977. Effects of abandoned lead and zinc mines and tailings piles on water quality in the Joplin area, Missouri. 55 p. U.S. Geol Surv., Rolla, Mo. [Available NTIS as PB-274-392/OGA.]

issolved zinc concentrations average 9 400 micrograms/liter in water from abandoned lead and inc mines, some of which discharge at the surface. Contamination of the shallow aquifer cherty limestones) by the highly mineralized mine water is limited to the immediate mining rea. The quality of water in the deep aquifer (cherty dolomites and sandstone) is generally xcellent. Dissolved zinc concentrations average 16 000 micrograms/liter in runoff from ailings areas. During a summer storm, however, runoff from a 7-acre tailings area contained aximum dissolved zinc, lead, and cadmium concentrations of 200 000; 400; and 1 400 microrams/liter, respectively. Mine-water discharges increase dissolved zinc concentrations in eceiving streams from a background of about 50 micrograms/liter to about 500 micrograms/liter uring periods of low flow. The higher concentrations are sustained during high flow by unoff from the tailings areas. Deposition of tailings on stream bottoms increases zinc oncentrations in bottom material from a background of about 100 micrograms/gram to about 500 micrograms/gram and increase lead concentrations in bottom material from about 20 icrograms/gram to about 450 micrograms/gram.

34. U.S. Geological Survey.
1976. Water-resources investigations of the U.S. Geological Survey in the major coal and oil shale areas of Wyoming, 1975-76. 43 p. U.S. Geol. Surv., Cheyenne, Wyo., open-file report.

35. U.S. Geological Survey.
1976. Hydrologic studies by the U.S. Geological Survey in oil-shale areas of Colorado, Utah, and Wyoming, 1976. 88 p. U.S. Geol. Surv., Cheyenne, Wyo., open-file report, February.

36. Van Zandt, T.
1975. Water for oil shale: some institutional alternatives for water allocation in arid rural regions. Water Resour. Bull. 11(6):1181-1186.

37. Water for Energy Management Team.
1974. Water for energy in the upper Colorado River Basin. 71 p. Dep. of the Interior, Eng. and Res. Center, Denver, Colo.

38. Weeks, J. B.
1976. Ground-water problems with oil shale mining in the Piceance Basin. Water Spectrum 8(1):8-14.

39. Weeks, J. B., and others.
1975. Simulated effects of oil shale development on the hydrology of Piceance Basin, Colorado. U.S. Geol. Surv., Prof. Pap. 908, 84 p. Reston, Va.

40. West, S. W.
1972. Disposal of uranium mill effluent by well injection in the Grants area, Valencia County, New Mexico. U.S. Geol. Surv. Prof. Pap. 386-D, 28 p.

41. Western Technology and Engineering, Inc.
1978. Mining and minerals fuels development in Montana's 208 study area: implication to water quality, final draft prepared for statewide 208 program. 191 p. Prepared for Mont. Dep. Health and Environ. Sci., Water Qual. Bur., Helena.

42. Wilson, D. W.
1977. Evaluation of regional effects of effluents from uranium production in New Mexico. 13 p. Lawrence Livermore Lab., Calif. Univ., Livermore. [Available NTIS as UCRL-13802.]

e Grants Uranium Region is a 2,600-mile area of north central New Mexico that has produced out 40 percent of all domestic uranium, and holds over one-half of the current reserves. e increasing demand for uranium to fuel commercial nuclear power plants is resulting in pid growth of the uranium industry and economic, social, and environmental changes are curring. One of the environmental issues of this region is the concern for eventually

unacceptable levels of air and water pollution from effluents from uranium mill tailings piles. This study addresses these potential impacts in relation to industrial environmental control practices, siting features, and other regional/temporal variables, including rates of production, locations and sizes of new mills, and population distributions.

343. Wixson, B. G., and E. Bolter.
1972. Evaluation of stream pollution and trace substances in the New Lead Belt of Missouri. In Trace substances in environmental health. p. 143-152. D. D. Hemphill ed. Univ. Missouri, Columbia.

In stream pollution studies carried out in the "New Lead Belt" of southeastern Missouri, data were collected to evaluate the effects of trace substances in wastes of lead-zinc mining operations, the character of individual wastes, and the effectiveness of stabilization lagoons in treating discharges. Samples from mine discharge water, combined mine-mill effluent, lagoon system effluent, and streams below the mine lagoons were taken and compared with contro site samples from unpolluted streams. Biological, chemical, and physical parameters were evaluated, along with trace metal determinations of lead, zinc, and copper. Mining wastewater contains carbon dioxide and sufficient phosphorus to combine with nitrogen present in stream water and cause undesirable benthic growths in bacterial-algal mats. Recommendations include recycling of milling wastewater and separate treatment of mine discharge water; treatment of tailings wastewater and baffled or submerged discharge outlets; and final treatme lagoons to remove colloidal material, trace substances, and metals by biological treatment.

344. Wixson, B. G., and H. W. Chen.
1970. Stream pollution in the "New Lead Belt" of S.E. Missouri. 23 p. Missouri Water Resour. Res. Cent., Columbia. [Available NTIS as PB-195 285.]

The project studied the effects of lead-zinc mining and milling pollution in the Viburnum Trend or "New Lead Belt" of southeastern Missouri. Results obtained from the project included the following: stream pollution below the mine discharge was mainly due to the growth of large algal mats of oscillatoria and bacteria which appear to result from the discharge of sodium isopropyl xanthate in the milling wastewater; limits were established for the precipitation of lead, zinc, and copper in relationship to pH and other water quality parameters; the amount of fluorides in the streams may be used as an indicator of mining water discharges; new techni may be used to evaluate organic milling reagents in the water and in the biota; diatoms may be used as biological indicators of mine wastewater effects.

345. Wymore, I. F., W. D. Striffler, and W. A. Berg.
1974. Water requirements for stabilizing and vegetating spent shale in the Piceance Basin. In Surface rehabilitation of land disturbances resulting from oil shale development, executive summary. p. 47-56. C. W. Cook, ed. Colo. State Univ., Fort Collins, Environ. Resour. Cent. Infor. Ser. 11, 56 p.

346. Zellars-Williams, Inc.
1977. Water recirculation system of central Florida phosphate mining. 97 p. Zellars-Williams, Inc., Lakeland, Fla. [Available NTIS as PB-270 359/3ST.]

This report presents a model of water use and recycling at three active central Florida phosphate mines. Water balances for two mines are constructed for two different years to illustrate the effects of seasonal fluctuations and system flexibility. The recirculating water systems of active central Florida mines are used to convey and process the ore, transpo and store sand and clay wastes, and reclaim the water for reuse. This preliminary study highlights the complexity and diversity of mine water systems while explaining the basic concepts required for their analysis.

2. ACID MINE DRAINAGE

347. Ciolkosz, E. J., L. T. Kardos, R. C. Cronce, and others.
1978. Soil as a medium for the renovation of acid mine drainage water: part I. Soil-water quality and vegetative responses. 242 p. Dep. Agron., Penn. State Univ., University Park. [Available NTIS as PB 278 161/5ST.]

This study determined the feasibility of using soil as a medium for the renovation of acid mine drainage water. The effects of liming and three levels of irrigation with acid water were studied. Acid water from a stream was applied weekly at three levels to an unlimed and a limed flood plain soil. Soil water samples were collected weekly. The soil water samples and the acid water applied were analyzed for pH, total acidity, conductivity, Al, Fe, Mn, SO_4, Ca, Mg, K, and Na. Perennial ryegrass and tall fescue were planted in separate halves of each experimental unit. During the study, the grasses were measured for yield, height, stand density, and percent cover. Both the unlimed and limed areas initially had considerable capacity for renovating the applied acid water. Liming and the weekly levels of acid water irrigation significantly affected the growth of perennial ryegrass and tall fescue.

348. Ciolkosz, E. J., L. T. Kardos, R. C. Cronce, and others.
1978. Soil as a medium for the renovation of acid mine drainage water: part II. Soil physical and chemical changes. 161 p. Dep. Agron., Penn. State Univ., University Park. [Available NTIS as PB 278 162/3ST.]

Acid coal mine water was applied to a Linden sandy loam soil at various levels. The soil data indicated that the main reactions between the applied water and the soil occurred in the upper part of the soil profile. The cation exchange capacity of the soil appeared to be the most important soil property affecting the renovation of the acid water. The basic cations were removed from the soil in the upper part of the profile and exchanged for H and Al in the water, thus causing the acidity of the soil to increase and the pH of the water to increase. Amounts of Ca and Na in the soil decreased, while the amount of the exchange acidity, K, and Al increased from acid mine water application. The Ca:Mg ratio of the soil decreased as a result of the treatment. Soil temperatures were lower in the irrigated areas than in the unirrigated areas. Apparently the better stand of vegetation in the irrigated area shaded the soil more and thus lowered its temperature.

349. Crane, M.
1974. The use of a fluidized bed electrode for the removal of dissolved iron from acid mine drainage. Ph.D. thesis. New York Univ., New York. 83 p. [Diss. Abstr. Int. 35/08-B:3892.]

350. Cywin, A.
1970. Neutralization of ferrous iron-containing acid wastes. 4 p. U.S. Environ. Protect. Agency, Washington, D.C. [Available NTIS as PB-236 528/6SL.]

The patent describes the neutralization of acid wastewaters containing ferrous iron using limestone in a finely divided state. Substantial amounts of a mixed valence, hydrous iron oxide sludge are recycled back to the dense, easily dewatered sludge to improve handling characteristics.

351. Franco, N. B., and R. A. Balouskus.
1974. Electrochemical removal of heavy metals from acid mine drainage. 97 p. U.S. Environ. Protect. Agency, Environ. Protect. Tech. Series, Proj. EPA-14010-GAO. Washington, D.C. [Available NTIS as PB-232 746/1.]

Laboratory and field studies were conducted to determine the economics of ferrous iron oxidation in a cell containing a bed of conductive particles in the space between the cathode and the anode. The effects of the process on other heavy metals present in acid mine drainage (AMD) and on the character of solids precipitated during treatment of low acidity water were also observed. An 18.9 liter/min (5 gal/min) pilot plant was operated at an actual mine site to evaluate treatment of 40 and 250 ppm ferrous iron AMD at pH levels of 2 and 5. A conventional aeration system was also included to generate comparative data. Estimates for a 473 liter/min (125 gal/min) plant based on the pilot data for oxidation only indicate that capital and operating costs for electrochemical treatment would be higher than those for aeration by factors of 5 and 1.7, respectively.

352. Fuller, R. H., J. M Shay, R. F. Ferreira, and others.
1978. An evaluation of problems arising from acid mine drainage in the vicinity of Shasta Lake, Shasta County, California. 14 p. Water Resour. Div., U.S. Geol. Surv., Menlo Park, Calif. [Available NTIS as PB-284 667/3ST.]

Streams draining the mined areas of massive sulfide ore deposits in the East and West Shasta Mining Districts of northern California are generally acid and contain large concentrations of dissolved metals, including iron, copper, and zinc. The streams, including Flat, Little Backbone, Spring, West Squaw, Horse, and Town Creeks, discharge into Shasta Lake and Sacramento River and have caused numerous fish kills. The major source of pollution is discharge from underground mines. A secondary source of pollution is streamflow and surface runoff that have passed through mine dumps where the oxidation of pyrite and other sulfide minerals results in the production of acid and the mobilization of metals. Suggested methods of treatment include the use of air and hydraulic sealing of the mines, lime neutralization of mine effluent, channeling of runoff and mine effluent away from mine and tailing areas, and the grading and sealing of mine dumps.

353. Grady, W. C., and D. J. Akers.
1976. Utilization of acid mine drainage treatment sludge. West Virginia Univ., Morgantown, Coal Res. Bur. Sch. Mines Tech. Rep. 132, 20 p.

Acid mine drainage treatment sludge can be used, with little modification, as a neutralizing agent for strip mine soils to aid in revegetation of mined areas. Dried and powdered sludge can be used as a substitute or additive to limestone in rock-dusting underground coal mines. A ceramic structural product can be produced by firing pretreated and preformed sludge to a temperature of 1 250°C. This material has a crush strength in excess of 800 lb/inch. Utilization as cement aggregate and recovery of metals and minerals are also discussed.

354. King, D. L., and J. J. Simmler.
1973. Organic wastes as a means of accelerating recovery of acid strip-mine lakes. 70 p. Missouri Water Resour. Res. Cent., Columbia. [Available NTIS as PB-219 264/9.]

The study determines the role of metals in the natural and accelerated recovery of strip-mine waters from the time of acid formation on the pyrite crystal to the time of lake recovery. A host of acid dissociated ionic species, including iron, sulfate, hydrogen, aluminum, manganese, calcium, and magnesium, and allochthonous organic materials characterize the chemistry of these lakes. The metal buffers are responsible for the long natural recovery times associated with all acid strip-mine lakes. The amount of such buffers depends upon the amount and type of clays and minerals and is dependent on the availability of carbon sources for sulfate reducing bacteria to use as food while they "titrate" the acidity by releasing H_2S to the atmosphere until all buffers are exhausted.

355. Kugatow, M. A.
1977. Mediation of acid strip mine pollution by the attempted inhibition of the iron-oxidizing autotroph, *Thiobacillus ferrooxidans*. D.Ed. thesis. Penn. State Univ. 68 p. [Diss. Abstr. Int. 38/10-B:4597.]

356. Larsen, H. P., and L. W. Ross.
1976. Two-stage process chemically treats mine drainage to remove dissolved metals. Eng. Min. J. 177(2):94-96.

Treatment of mine drainage waters has fast become a necessity for all mining operations, and regulations governing discharge into local waterways can be expected to become even more stringent. One aspect of mine water treatment--removal of dissolved metals--can be accomplishe by a two-stage process developed at the Denver Research Institute (DRI). The first stage of the process treats the waters by lime neutralization to eliminate Fe and Al. A second stage then removes Cu, Zn, Mn, and heavy toxic metals (Hg, Cd, As) by adding sulfide to the waters. The quantitative effects of both stages of treatment can be predicted by a mathematical description based on the equilibrium relations involved.

357. Long, D. A., J. L. Butler, and M. J. Lenkevich.
1977. Soda ash treatment of neutralized mine drainage. 76 p. Gwin, Dobson, and Foreman, Inc., Altoona, Penn. [Available NTIS as PB-272 760/OST.]

Utilization of acid mine drainage (AMD) streams as a source of potable and industrial water has become a major goal of several proposed AMD treatment schemes. From among the various schemes available, the lime neutralization/soda ash softening process was selected for use at Altoona, Penn. The treatment plant, as constructed, has the capability of treating waters from Kittanning Run (acid mine polluted) alone or in combination with waters from other city sources to achieve: (1) neutralization and iron removal to levels satisfactory for stream release, (2) softening to approximately 100 mg/l $CaCO_3$ hardness for municipal use, and (3) softening to a hardness of 200 mg/l $CaCO_3$ or higher to meet industrial use requirements. The objective of this study was to evaluate the technical and economic feasibility of softening neutralized AMD waters by means of the cold lime/soda ash process. The study was conducted full-scale at the Altoona Treatment Plant located near the Horseshoe Curve area of Altoona, Penn. Unit processes employed at the plant consisted of lime neutralization, aeration, settling, soda ash softening, recarbonation, and filtration.

358. McPhilliamy, S. C., and J. Green.
1973. A chemical and biological evaluation of three mine drainage treatment plants. 81 p. Surveillance and Analysis Div., Environ. Protect. Agency, Wheeling, W.Va. [Available NTIS as PB-254 543/4ST.]

Chemical and biological sampling was conducted at three mine drainage treatment plants operating in Washington County, Penn. In addition to the parameters generally associated with mine drainage, 10 additional parameters were included for analysis during three of the four sampling rounds. These metals were manganese, aluminum, calcium, magnesium, cadmium, chromium, copper, lead, nickel, and zinc. They were included in a general attempt to observe the efficiency of a conventional mine drainage treatment plant for the removal or reduction of metals not commonly associated with mine drainage but often present in measurable quantities.

359. Miller, J. D.
1972. Removal of dissolved contaminants from mine drainage. 61 p. Univ. Utah, Salt Lake City. [Available NTIS as PB-214 563/6ST.]

Eleven mill tailing samples from locations throughout the Rocky Mountain region were tested for their effectiveness in removal of dissolved contaminants from mine drainage. The average capacity of the tailings tested was 9.8 mg of iron per gram of tailing with a range of capacities from 6 mg/g to 15 mg/g. From these studies it was concluded that for almost all tailing samples, removal was accomplished mainly due to hydrolytic absorption of metal ions with a small contribution due to the inherent basicity of the tailing. In the other case, removal occurred via reaction with calcareous components of the sample. Continuous column, or stationary bed tests, in the laboratory and in the field, were not nearly as effective. It appears that for effective removal a stirred tank reactor will be required.

360. Montana Department of Natural Resources and Conservation.
1977. Feasibility of silver-lead mine waste manipulation for mine drainage control. 109 p. Mont. Dep. Nat. Resour. and Conserv., Helena. [Available NTIS as PB-276 599/8ST.]

The purpose of the feasibility study, Dry Fork of Belt Creek, Mont., is to examine solutions and methods of abatement of acid mine drainage problems, and recommend a solution. The Galena Creek area in the Dry Fork of Belt Creek drainage contains several old mine tailings piles from which acidic waters emerge. The acidic water has destroyed the aquatic life in Galena Creek and the Dry Fork of Belt Creek as well as ruined the overall esthetic value of both creeks. Mine dump surface regrading and sealing are recommended as the method of reducing the acidic wastes entering Galena Creek. The top of Block P Mine dump should be sloped so as to allow proper drainage. The top should also be sealed with a bentonite seal, and top soil added to allow revegetation. The bypass pipeline around the Block P dump should be extended to prevent water in Galena Creek from creating seeps in the toe of the dump.

361. Nebgen, J. W., D. F. Weatherman, M. Valentine, and others.
1976. Treatment of acid mine drainage by the alumina-lime-soda process. 105 p. Midwest Res. Inst., Kansas City, Mo. [Available NTIS as PB-259 930/6ST.]

The alumina-lime-soda process is a chemical desalination process for waters in which the principal sources of salinity are sulfate salts. The process has been field tested at the Commonwealth of Pennsylvania's Acid Mine Drainage Research Facility, Hollywood, Penn., as a method to recover potable water from acid mine drainage. The alumina-lime-soda process involve two treatment stages. Raw water is reacted with sodium aluminate and lime in the first stage to precipitate dissolved sulfate as calcium sulfoaluminate. In the second stage, the alkaline water (pH = 12.0) recovered from the first stage is carbonated to precipitate excess hardness. Following carbonation, product water meets U.S. Public Health Service specifications for drinking water. Alumina-lime-soda process economics are influenced most by the cost of sodium aluminate.

362. Olem, H.
1975. The rotating biological contactor for biochemical ferrous iron oxidation in the treatment of coal mine drainage. 85 p. Penn. State Univ., University Park. [Avail NTIS as PB-264 534/9ST.]

Pilot scale testing of the rotating biological contactor for the oxidation of ferrous iron in acid coal mine drainage has shown the process to be dependable, efficient, and economically comparable to purely chemical methods of iron oxidation. The 0.5-meter device consisted of four sets of plastic discs affixed to a centralized shaft. As the discs rotated half immersed in flowing mine water, an average iron-oxidizing bacterial population of 70,000 cells per square centimeter colonized the disc surfaces without prior bacterial preseeding or nutrient supplementation. Concentration dependent first order kinetics were established during continu operation from May 1974 through March 1975 at several hydraulic loading and disc rotation rates. Hydraulic loadings of 2.7 and 5.4 gal/day/ft^2 (0.11 and 0.22 m^3/day/m^2) at optimum disc rotation resulted in the transformation of an average 240 mg/l influent ferrous iron to produce effluents of 2 and 5 mg/l, respectively. Performance was not impaired when operated at mine water temperatures as low as 8°C and the process was shown to recover rapidly when subjected to artificially induced toxicity in the form of a strong disinfectant solution. The process prepared a coal mine drainage containing up to 313 mg/l of ferrous iron for limestone neutralization and subsequent solids precipitation at an estimated operating cost of 4 cents per thousand gallons (1 cent per cubic meter).

363. Pearson, F. H., and J. B. Nesbitt.
1972. Combined treatment of municipal wastewater and acid mine drainage system. 50 p. Inst. for Research on Land and Water Resources, Penn. State Univ., University Park. [Available NTIS as PB-222 936/7.]

Acid mine drainage (AMD), a serious water pollutant in many states, may be an economical source of ferrous iron for the chemical coagulation of municipal wastewater. AMD would then be neutralized by the alkalinity in wastewater. Samples of AMD and raw wastewater were collected from sites in Pennsylvania where AMD was found close to a wastewater treatment plant. The samples were mixed in varying ratios, then processed at controlled pH in a laborat scale treatment plant that provided flocculation and sedimentation. The optimal pH was 8 for a maximum reduction in phosphorus, ferrous iron, and turbidity. At pH 8 the median reduction in total phosphorus was 95 percent when the molar ratio of ferrous iron to phosphorus was 2. Ferrous iron was almost completely removed at pH 8. A cost analysis is given for the maximum distance for which it is economical to pump AMD for combined treatment with wastewater.

364. Rabe, R. W., R. C. Wissmer, and R. F. Minter.
1973. Plankton populations and some effects of mine drainage on primary productivity of the Coeur d'Alene River, Delta, and Lake. 28 p. Water Resour. Res. Inst., Univ. Idaho, Moscow. [Available NTIS as PB-216 811/0.]

Variations in primary production and physiochemical measurements in the Coeur d'Alene River and Lake in Idaho were examined. These bodies of water have received mine tailings and metallic sulfide minerals for the last 80 years. Metal concentrations of Md, Cd, Mg, Ca, Pb, Cu, Zn, Fe, Na, and K; water quality; and phytoplankton composition-density were determined. Additional sampling included unpolluted portions of Coeur d'Alene Lake and the unaffected St. Joe River. Nannoplankton from Coeur d'Alene Lake were exposed to known concentrations of Cu^{2+}, Zn^{2+}, and dilutions of Coeur d'Alene River water under controlled light and temperature. Inhibitory effects of separate and interacting metals on carbon 14 uptake by algae were assessed with factorial bioassays and response surfaces.

365. Ross, L. W.
1973. Removal of heavy metals from mine drainage by precipitation. 71 p. Dep. Chem. Eng. and Metallurgy, Denver Univ., Colo. [Available NTIS as PB-228 584/9ST.]

Heavy metals in mine drainage waters of the Rocky Mountains can be removed by a two-stage process consisting of neutralization followed by sulfide treatment. The first stage removes ferric and aluminum hydroxides, and the second (sulfide) stage precipitates the heavy metals that are most objectionable as pollutants, and that are of possible interest for economic recovery. The two-stage process has been demonstrated in the laboratory and in a field experiment.

366. Svanks, K., and K. S. Shumate.
1973. Factors controlling sludge density during acid mine drainage neutralization. 156 p. Water Resour. Cent., Ohio State Univ., Columbus. [Available NTIS as PB-226 615/3.]

Laboratory scale experiments were employed to investigate the feasibility of coal mine drainage neutralization treatment with the formation of magnetite and other high density/low volume sludges. Where applicable, the effects of bacterial catalysis on ferrous iron oxidation were incorporated into the investigations. Major process types studied included magnetite formation and high density sludge from lime treatment of acid mine drainage. Both acidic iron solutions and synthetic acid mine drainage were studied, primarily in batch process reaction systems, both with and without sludge recycle. Emphasis was placed on development of a basic understanding of the results observed, and interpretations drawn heavily from both experimental results and an incisive literature review.

367. Wilmoth, R. C.
1974. Limestone and limestone-lime neutralization of acid mine drainage. 101 p. Crown Mine Drainage Control Field Site, Environ. Protect. Agency, Riversville, W.Va. [Available NTIS as PB-237 607/0ST.]

The critical parameters affecting neutralization of ferric-iron acid mine waters were characterized by the Environmental Protection Agency in comparative studies using hydrated lime, rock-dust limestone, and a combination of the two as neutralizing agents. The advantages and disadvantages of each of these neutralizing agents were noted. On the ferric-iron test water, combination limestone-lime treatment provided a better than 25 percent reduction in materials cost as compared to straight lime or limestone treatment. Significant reduction in sludge production was noted by the use of rock-dust limestone and by the use of combination treatment as compared to hydrated-lime treatment. Emphasis on optimizing limestone utilization efficien- ies resulted in an increase from approximately 35 to 50 percent utilization. Studies using imestone that had been ground to pass a 400-mesh screen resulted in utilization efficiencies ear 90 percent.

368. Wilmoth, R. C.
1978. Combination limestone-lime neutralization of ferrous iron acid mine drainage. 63 p. Industrial Environmental Research Lab., Cincinnati, Ohio. [Available NTIS as PB-280 169/4ST.]

Studies were conducted on ferrous-iron acid mine drainage (AMD) treatment by a two-step neutral zation process in which rock-dust limestone was mixed with the influent AMD and the hydrated lime was added in a polishing reactor. This combination treatment process resulted in reagent consumption cost reductions as high as 30 percent as compared to single-stage lime treatment of the same AMD. Later data indicated that an equal cost reduction (compared to single-stage lime treatment) could be achieved by a two-stage hydrated lime process in which the AMD and recycled sludge were mixed in the first reaction vessel and hydrated lime was added in the second reactor. No cost advantage for the combination process over straight hydrated lime treatment seemed to exist in situations where sludge recycling was not employed.

369. Wilmoth, R. C., and R. B. Scott.
1970. Reverse osmosis treatment of concentrated ferrous iron acid mine drainage. 16 p. Norton Mine Drainage Filed Site, Fed. Water Qual. Admin., Norton, W.Va. [Available NTIS as PB-216 359.]

A 4,000 gal/day reverse osmosis unit was tested on a severely polluted ferrous iron acid mine discharge near Morgantown, W.Va. The water recovery rate was limited to 50 percent due to membrane fouling problems. The role of ferrous iron fouling could not be identified because of a predominance of calcium sulfate precipitation on the membranes. The feasibility of rever osmosis treatment is doubtful for mine drainage having concentrations of acidity, iron, sulfat and calcium as high as 5 000 mg/l, 2 300 mg/l, 10 000 mg/l and 525 mg/l, respectively, due to the membrane fouling problem, maximum recoveries of only 50 percent, and the nonpotable quality of the product water.

3. EFFECTS ON AQUATIC ECOLOGY AND BIOTA

370. Bell, D. M.
1977. Effects of a zinc mine groundwater effluent on a stream diatom community. Periphyton. Proc. Penn. Acad. Sci. 51(1):51-53.

371. Brown, B. E.
1976. Observations on the tolerance of the isopod *Aesellus meridianus* (Rac.) to copper and lead. Water Res. 10:555-559.

Aesellus meridianus from sites receiving mine-drainage in the Hayle and Gannel Rivers in Cornwall exhibited, in toxicity tests and growth rate experiments, particular tolerance to copper and lead. Isopods from the Hayle, a river high in concentrations of copper in both water and sediments and low lead concentrations, were tolerant to both copper and lead. Isopods from the Gannel, a river with moderately high concentrations of copper and exceptional high concentrations of lead, were tolerant to lead only. Tolerance to lead was shown to persist in animals from the Gannel F_2 generation that had been cultured in the laboratory.

372. Cumming, K. B., and D. M. Hill.
1971. Stream faunal recovery after manganese strip mine reclamation. 41 p. Coop. Fish. Unit., Virginia Polytech. Inst., Blacksburg. [Available NTIS as PB-206 184.]

The results of the investigation suggest a number of conditions to be met for effective reclamation, particularly of manganese strip mines, and in general of any surface mining that tends to increase the degree of siltation and turbidity in receiving waters. Seasonal monitoring of certain chemical, physical, and biological parameters of streams draining manganese strip mine spoils in three stages of reclamation verified that the community structure of fish and benthic macroinvertebrates in these streams remains severely depressed until complete reclamation of the spoils has been accomplished. Laboratory studies established the median tolerance limits of three native species of fishes to silt in suspension and to manganese ions. These studies suggest that the principal factor depressing the faunal communities in partially reclaimed and unreclaimed streams is the chronically high degree of turbidity and siltation.

573. Dills, G. G., and D. I. Rogers, Jr.
1972. Aquatic-biotic community structure as an indicator of pollution. 31 p. Geol. Surv. of Alabama Univ. [Available NTIS as PB-216 801/1.]

Generally aquatic systems exposed to environmental stress (pollution) have fewer species and less diversity than naturally occurring communities. In the present study physiochemical conditions and community structure of benthic macroinvertebrates were investigated in a drainage system polluted with acid mine drainage. A statistical interpretation was performed to show possible correlation between water parameters and species diversity. The applicability of using the macroinvertebrate community structure to evaluate stream conditions consequent to acid flow is discussed.

574. Gale, W. L., and others.
1974. The impact of lead mine and mill effluent on aquatic life. In Forty-Seventh Annual Meeting and Thirty-Fifth Annual Mining Symposium, Proc. [Duluth, Minn., Jan. 16-18.] p. 76-81. P. J. Fedkenheuer, ed. Am. Inst. Mining, Metallurgical, and Petroleum Eng., Minn. Sec., and Univ. Minn., Minneapolis, Min. Resour. Res. Cent. 150 p.

The rapid development of Missouri's New Lead Belt into the world's largest lead producing region has been accompanied by a number of local alterations in the Ozark stream environment. Research findings are presented as to the probable and potential causes of stream alteration by the effluent from lead-zinc mines and associated mills. Comparison of relatively unaffected or "nonpolluted" streams and those streams which consistently demonstrate marked alteration have been evaluated with a comparative study of the different industrial practices and various hemical and physical parameters employed in extractive metallurgy. Industrial techniques or procedures that are most likely responsible for environmental alteration are defined, along with suggestions for pollution control methods.

75. Gale, N. L., P. Marcellus, and G. Underwood.
1974. Life, liberty and the pursuit of lead: the impact of lead mining and milling activities on aquatic organisms. In Trace Contam. Conf. 2d Annu. Proc. [Pacific Grove, Calif., August.] p. 295-307.

ound lead in field or laboratory specimens was removed by washing with ethylenediaminetetracetate (EDTA) in concentrations as low as 0.01 M at pH 7.5. The results of analyses of arious consumer organisms have indicated no biomagnification of lead in the grazing food hains involving aquatic vegetation. Data in tabular and graphical form are appended.

76. Hawkes, C. L.
1979. Aquatic habitat of coal and bentonite clay strip mine ponds in the northern Great Plains. In Ecology and coal resource development, vol. 2. p. 609-614. Mohan K. Wali, ed. Pergamon Press, New York.

77. Justyn, J., and S. Lusk.
1976. Evaluation of natural radionuclide contamination of fishes in streams affected by uranium ore mining and milling. Zool. Listy 25(3):265-274.

78. Klose, P. N.
1978. Effects of a zinc mine effluent on the benthic macroinvertebrate fauna of Saucon Creek, Lehigh and Northhampton Counties, Pennsylvania. Ph.D. thesis. Lehigh Univ., Bethlehem, Penn. 214 p. [Diss. Abstr. Int. 39/03-B:1113.]

379. Lewis, M. A.
1977. Aquatic inhabitants of a mine waste stream in Arizona. USDA For. Serv. Res. Note RM-349, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

380. Lewis, M. A.
1977. Influence of an open-pit copper mine on the ecology of an upper Sonoran intermittent stream. Ph.D. thesis. Ariz. State Univ., Tempe. 122 p. [Diss. Abstr. Int. 38/03-B:1033.]

381. Lewis, M. A.
1978. Acute toxicity of copper, zinc, and manganese in single and mixed salt solutions to juvenile longfin dace, *Agrosia chrysogaster*. J. Fish. Biol. 13:695-700.

382. Lewis, M. A.
1979. Impact of copper-mining on the ecology of a desert intermittent stream in centra Arizona: a summary. J. Ariz.-Nev. Acad. Sci. 14:22-30. [Abbreviated form of Ph.D. dissertation (Ariz. State Univ.) entitled, "Influence of an open-pit copper mine on the ecology of an upper Sonoran intermittent stream."]

383. Lewis, M. A., and S. Gerking.
1979. Summer primary productivity in an intermittent desert stream. Am. Midl. Nat. 102:172-174.

Estimate of primary productivity in a mine-polluted stream.

384. Lind, O. T., and R. S. Campbell.
1970. Community metabolism in acid and alkaline strip-mine lakes. Trans. Am. Fish. Soc. 99(3):577-582.

Community metabolism was measured over a 24-month period by a modified dial oxygen procedure in three Missouri strip-mine lakes, one acid and two formerly acid. Water pH ranged from 3.2 to 8.1. Biotic diversity was inversely related to acidity. Maximum daily values of gross photosynthesis were similar in the lakes (7.9, 7.6, and 6.5 g O_2/m^2/day, but the highest rates of annual gross volumetric photosynthesis (586 and 682 g O_2/m^3/yr) were found in the more nearly eutrophic alkaline lake. Community respiration values, which were reasonably similar in the lakes, were considerably lower than in ponds and Texas coastal bays of similar photic depth. Rates of community respiration closely paralleled gross photosynthesis so that the photosynthesis:respiration ratio of each lake fluctuated about unity. Community function in these acid and alkaline lakes, judged by miles of photosynthesis and respiration, compares favorably with community function in nonacid natural waters.

385. McMahon, B., P. McCart, A. Peltzner, and others.
1977. Toxicity of saline groundwater from Syncrude's Lease 17 to fish and benthic macroinvertebrates. Syncrude Canada Ltd., Environ. Res. Monogr. 1977-3, 99 p.

The mining of the tar sands that are included in the area to be developed by Syncrude Canada Ltd. will require the dewatering of the mine pits. This will involve the pumping of large volumes of saline groundwater. Present plans call for its eventual disposal through Ruth Lake, the Poplar River, and, finally, the Athabasca River. This study was designed to determi whether groundwater from the mine area is toxic to aquatic organisms and, if so, the concentrations at which this toxicity is expressed. A variety of species, including both fish and aquatic insects, was tested to determine the range of sensitivity among aquatic animals. The resultant data can, with some qualifications, be used to estimate the maximum safe concentrati of groundwater that can be added to natural waters with minimal risk of toxic effects.

386. Norton, L. R., and N. R. Chymko.
1978. Water quality and aquatic resources of the Beaver Creek diversion system, 1977. Syncrude Canada Ltd., Environ. Res. Mongr. 1978-3, 340 p.

ater quality and aquatic resources of the system that was formed when Beaver Creek was diverted way from the developed area were studied from March to November 1977. Two newly created ater bodies were characterized.

87. Platts, W. S., and S. B. Martin.
1978. Hydrochemical influences on the fishing within the phosphate mining area of eastern Idaho. USDA For. Serv. Res. Note INT-246, 15 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

88. Sherk, J. A., Jr.
1969. Effects of low levels of phosphate mining effluent on periphyton in controlled artificial estuaries. Ph.D. diss. North Carolina State Univ., Raleigh. 89 p. [Diss. Abstr. Int. 30/11B:5123.]

89. Sigler, W. F., W. T. Helm, J. W. Angelovic, and others.
1966. The effects of uranium mill wastes on stream biota. Utah Agric. Exp. Stn. Bull. 462, 76 p. Logan, Utah.

90. Sykora, J. L., and others.
1975. Some observations on spawning of brook trout (*Salvelinus fontinalis* Mitchill) in lime neutralized iron hydroxide suspensions. Water Res. 9(4):451-458.

91. Van Meter, W. P.
1974. Heavy metal concentration in fish tissue of the upper Clark Fork River. 45 p. Water Resour. Res. Cent., Mont. State Univ., Bozeman. [Available NTIS as PB-237 429/6ST.]

pecimens of game and rough fish from the upper Clark Fork River basin of western Montana have een analyzed by atomic absorption spectroscopy for cadmium, copper, lead, mercury, and zinc. oth muscle and liver tissue were analyzed. Procedures for the analyses are described in etail, including a sealed Pyrex tube method for the wet digestion of fresh tissue samples. arts of the Flint Creek drainage are contaminated with mercury. Muscle concentrations in rout ranged up to 1.9 p/m. The mercury results from silver ore processing in the 19th century y the pan amalgamation method. Elevated levels of cadmium were found in one stream, the ittle Blackfoot River, but no apparent source can now be identified.

92. Zitko, V., and W. G. Carson.
1977. Seasonal and developmental variation in the lethality of zinc to juvenile Atlantic salmon (*Salmo salan*). Mining pollution. J. Fish Res. Board Can. 34(1):139-141.

93. Zitko, V., W. V. Carson, and W. G. Carson.
1975. Thallium: occurrence in the environment and toxicity to fish. Bull. Environ. Contam. Toxicol. 13(1):23-30.

hallium is present in the effluents of the base-metal mining industry, and its acute toxicity juvenile Atlantic salmon is approximately equal to that of copper. The usual treatment of aste water with alkali to remove heavy metals by precipitation has little effect on thallium. he limited use of thallium will not lead to a global contamination of the environment, but ocalized problems may exist or develop in the future, mainly as a result of mineral processing.

G. Tailings, Spoils, Slimes, and Wastes

Section G contains citations on surface mine spoils; overburden; waste dumps; slime ponds and tailings ponds, dams, and piles. It includes citations of the chemistry and physical properties of the spoils, as well as tailings dam construction and methods of dewatering slime

394. Anderson, M. A., D. L. Sorensen, P. B. Porcella, and others.
    1976. Establishment of microbial populations in sterile mine spoils and overburden. II. Amendments required for acid mineral-mine spoils. 48 p. Utah Water Res. Lab., Logan.

Using mine spoil from the Blackbird Mine, Cobalt (near Salmon), Idaho, various combinations of nitrogen, phosphorus, chelators, trace elements, potassium, manure, and salt leaching were studied with the bioassay by microscopal observation and by measurement of nitrogen fixation and accumulation, dehydrogenase activity, chlorophyll accumulation, and other chemical paramet It was concluded that the limiting factors for microbial (algal) growth were (in order of importance): soil moisture, pH control, and phosphorus.

395. American Cyanamid Co.
    1969. Building land with phosphate wastes. Mining Eng. (New York) 21(12):38-40.

Disposal of phosphatic clays presents a costly problem to phosphate industry in Polk County, Fla., since it amounts to \$0.24/ton of product. American Cyanamid Co. developed a technique to dispose of about 50 percent of waste clays and to build usable land. This technique also provides the additional benefits of tailings disposal, increased water recovery, and one-third reduction in circulation and settling costs, and a substantial decrease in the number of dams required for settling areas.

396. Arizona Bureau of Mines.
    1971. Use of mineral waste products. Fieldnotes (Ariz. Bur. Mines) 1(2):4.

397. Bates, R. C.
    1977. Rock sealant restricts falling barometer effect. Mining Eng. (New York) 29(12):38-39.

This rebuttal to a previous article provides new insight into the use of sprayed sealants in uranium mines. The author rejects the idea that the value of rock sealant on radon control is destroyed by changes in barometric pressure, showing that this is not necessarily true. The analyses described demonstrate that radon contamination resulting from changing barometric pressures is reduced by a rock coating. The overall use of coatings depends on their costs an effectiveness as compared with other radon control measures.

398. Bendersky, D., and others.
    1977. A study of waste generation, treatment and disposal in the metals mining industr 407 p. Midwest Res. Inst. Kansas City, Mo. [Available NTIS as PB-261 052/5WN.]

399. Bolter, E., B. G. Wixson, D. L. Butherus, and others.
    1974. Distribution of heavy metals in soils near an active lead smelter. Am. Inst. Mech. Eng., Minn. Sec., 47th Annu. Meet., and 35th Univ. Minn. Annu. Mining Symp., Proc. p. 73-76.

The development of the 'New Lead Belt' or Viburnum Trend in southeast Missouri during the last decade has changed a sparsely populated, nonindustrialized area into the largest lead-producin mining district in the world. The growing concern over the impact of such a development on th ecology of the area prompted several companies and government agencies to support an interdisciplinary research project by scientists and engineers of the University of Missouri, Rolla and Columbia campuses, to delineate the extent of pollution, to determine individual pollution sources, and to suggest methods for the reduction or elimination of such problems. This paper describes the accumulation of heavy metals in soils caused by mining and smelting activities.

00. Borrowman, S. R., and P. T. Brooks.
1976. Radium removal from uranium ores and mill tailings. 16 p. Paper presented at the Am. Inst. Mech. Eng. Annu. Meet. [Chicago, Ill., 1973.] [Available NTIS as PB-250 751/5ST.]

01. Bortz, S. A.
1976. Utilization of mining and milling wastes. In Proc., Fifth Mineral Waste Utilization Symp. [April 13-14, 1976.] 21 p. IIT Research Inst., Chicago, Ill. [Available NTIS as PB-267 715/1ST.]

his report presents a review of studies and investigations concerning materials, energy, and roducts recovered from solid wastes. The bulk of the information presented is a summary of he "Fifth Mineral Waste Utilization Symposium" that was organized and presented as the principal bjective of this program. A total of 52 papers was presented. Contents: metal recovery; nergy recovery from solid wastes; waste utilization in construction; conclusion.

02. Campbell, J. A., W. A. Berg, and R. D. Heil.
1974. Physical and chemical characteristics of overburden, spoils and soils. In Surface rehabilitation of land disturbances resulting from oil shale development, executive summary. p. 31-39. C. W. Cook, ed. Colo. State Univ., Fort Collins, Environ. Resour. Cent., Infor. Series 11, 56 p.

03. Cannon, R. C., R. S. Ribas, J. Nickerson, and others.
1976. Elimination of washer slimes from the production of phosphate chemicals. 137 p. Fla. State Dep. Environ. Regulation, Tallahassee. [Available NTIS as PB-250 364/7ST.]

he report gives results of laboratory studies to determine the feasibility of a new phosphoric cid process involving dry mining of the matrix, calcination, and digestion with phosphoric/ ulfuric acid mixtures (five types of Florida phosphate matrices were used). Process steps ncluded upgrading the matrix by dry methods, calcination in a static bed, and digestion compar- ble to commercial dehydrate processes. The matrix samples were upgraded by removing clay hrough selective grinding and air classification, and by separation of the sand fraction lectrostatically. Typical clay removal values were 80-90 percent at a phosphate loss of 15-25 ercent. Calcination produced an acceptable phosphoric acid from good quality matrix, but ailed to reject metal impurities sufficiently to permit processing of poor-to-average matrix. alcination eliminated the interference of clay in the digestion and filtration steps. Addition f mineralizers had only marginal effects on metal solubility.

04. Chacho, E.
1978. Snow and erosion in the phosphate mining area of Idaho. Annu. Rep. 1977-78. 110 p. Univ. Idaho, Moscow.

his report covers four major subject areas: (1) meteorology in the mining area, (2) erosion rom mine dumps, (3) snow accumulation, distribution, and abaltion on a mine dump, and (4) the ize and location of snowdrifts in the mining area. Each subject is discussed separately in he report and consists of summaries of data and a brief account of the analysis completed to ate.

05. Clements, L. W., and others.
1975. Charcterization studies of Florida phosphate slimes. 8 p. U.S. Bur. Mines, Tuscaloosa Metallurgy Res. Lab., University, Ala.

06. Collins, R. J., and R. H. Miller.
1976. Availability of mining wastes and their potential for use as highway material, vol. I. Classification and technical and environmental analysis. 308 p. Valley Forge Labs., Inc., Devon, Penn. [Available NTIS as PB-266 170/0ST.]

Over 1.6 billion tons of mining and metallurgical wastes are produced each year. Although a small percentage of all this material is actually being used, a number of mining and metallurg wastes have been successfully utilized as highway construction material. A number of other mineral wastes are potentially useful with some degree of processing. Materials most highly recommended for use in highway construction are gold gravel, steel slag, lead-zinc chat, phos slag, taconite tailings, copper slag, and waste rock from the mining of copper, fluorspar, gold, and iron ore.

407. Collins, R. J.
1976. Availability of mining wastes and their potential for use as highway material, vol. II. Location of mining and metallurgical wastes and mining industry trends. 1 p. Valley Forge Labs., Inc., Devon, Penn. [Available NTIS as PB-266 171/8ST.]

This study was performed to determine the availability of mining and metallurgical wastes and to assess their potential for use in highway construction. A large number of information sources were used to develop an inventory and classification system for these wastes. Informa tion presented in volume II was obtained mainly from knowledgeable personnel in the mining industry and government agencies, supplemented by key reports and industry periodicals. Maps and tabulations of mineral wastes from 35 principal mining States are presented in this volum

408. Clifton, J. R., P. W. Brown, and G. Frohndorff.
1977. Survey of uses of waste materials in construction in the United States. 64 p. Materials and Composites Sec., Natl. Bur. Standards, Washington, D.C. [Available NTIS as PB-270 854/3ST.]

This survey covers the sources, amounts, and disposal of major mining, industrial, and munici wastes available in the 48 conterminous states of the United States along with their present and potential uses as construction materials. Wastes from mining, industrial, and municipal sources are treated separately and in that order, which is the order of decreasing amount of usable wastes available from each major classification. Wastes from mineral, metallic ore an coal mining operations are covered in section 2. Industrial wastes are treated in sections 3 to 5. Section 3 describes a variety of important wastes that have found few markets; byproduc from coal combustion are discussed in section 4; and section 5 covers slags, byproducts which are already extensively used as aggregates in construction but for which there may be higher value uses. Municipal wastes, including municipal refuse, incineration residue, glass, demoli tion waste, and sewage sludge, are the subject of section 6. Section 7 is directed toward som potential wastes that may be generated in substantial amounts by emerging technologies relate to energy production and environmental protection. Obstacles to and incentives for the increa use of waste materials in construction are discussed in section 8.

409. Colorado State University.
1976. Research needs for mining and industrial solid waste disposal. 40 p. Colo. State Univ., Fort Collins. [Available NTIS as PB-269 247/3ST.]

Representatives of the geotechnical and environmental engineering professions, industry, and governmental agencies participated in a 2-day workshop to identify research needs in the area of mining and industrial solid waste disposal. This report, which was prepared by the partici pants during the workshop, identifies 19 areas of needed research. The most critical need is for establishment of a reliable source of data concerning the magnitude of the waste disposal problems. Other areas of needed research are properties of wastes, seepage, surface stabiliza tion, tailing structures, field instrumentation, abandonment, materials handling, material placement, climatic conditions, spontaneous combustion, and new methods of disposal.

410. Culbertson, W. J., Jr., T. D. Nevens, and R. D. Hollingshead.
1970. Disposal of oil shale ash. Colo. Sch. Mines Quar. 64(4):89-132.

411. DePuit, E. G., J. G. Coenenberg, and K. J. Dollhopf.
1979. Salt translocation in saline-sodic mine spoils. Interim report: effects of fiel irrigation and amendment treatments on vegetation establishment in 1978. 33 p. Mont. Agric. Exp. Stn., Mont. State Univ., Bozeman.

upplemental irrigation significantly promoted seeded perennial grass establishment, productivity, nd canopy cover during the first growing season. Species most stimulated by irrigation were lender wheatgrass, smooth bromegrass, pubescent wheatgrass, and blue grama, although nearly ll other major established grasses were benefited to some extent. Invading weeds were consisently, although not significantly, reduced in irrigated as opposed to nonirrigated plots. lant community diversity was higher in irrigated than in nonirrigated plots. These shorterm, initial results suggest a great potential for use of irrigation in terms of enhancement f vegetation establishment. Further research is necessary, however, on long-term effects of rrigation and irrigation cessation on vegetational trends. First-year vegetation data showed o significant superiority of the four amendments over the nonamended control nor any significant ifferences among amendment treatments. It is believed that valid differences among amendment reatments and control plots may develop in the future, by which time sufficient plant root enetration and/or sodium upward or downward migration may cause changes in vegetation development.

12. Douglas, R. L., and J. M. Hans, Jr.
    1975. Gamma radiation surveys at inactive uranium mill sites. Off. Radiation Prog., Rep. No. ORP/LV-75-5, 97 p. Las Vegas, Nev.

13. Dreesen, D. R.
    1978. Uranium mill tailings - environmental implications. Los Alamos Sci. Lab. Mini-Review, LASL 77-37, 4 p.

14. Duncan, D. L., and G. G. Eadie.
    1974. Environmental surveys of the uranium mill tailings pile and surrounding areas, Salt Lake City, Utah. 131 p. Uranium Mining and Mill Tailings Proj., Off. Radiation Prog., Las Vegas, Nev. [Available NTIS as PB-241 247/6ST.]

nvironmental surveys have been conducted for the Utah State Division of Health's Occupational nd Radiological Health Section at the former Vitro Corporation uranium mill and in the Salt ake City, Utah, area. The surveys included measurement of external gamma radiation and airborne adioactivity. The results of the surveys indicated that: the external gamma radiation levels n the tailings area exceed recommended exposure limits; ambient levels of radon over the pile nd in structures built immediately adjacent to the tailings pile are above the currently ecommended concentration; tailings material has been removed from the Vitro site by persons nd used around dwellings and businesses; and tailings material has become windborne and eposited against dwellings and structures in the vicinity.

5. Engineering and Mining Journal.
    1971. Chemical treatment of waste tailings puts an end to dust storms. Eng. and Mining J. 172(4):104-105.

6. Engineering and Mining Journal.
    1978. Revolutionary thickener design tackles heavy flow of zinc mine tailings. Eng. and Mining J. 179(4):78-79.

7. Farmer, E. E., and B. Z. Richardson.
    1976. Hydrologic and soil properties of coal mine overburden piles in southeastern Montana. In Proc. of the Natl. Coal Assoc./Bituminous Coal Res. Coal Conf. and Expo III [Oct. 1976, Louisville, Ky.]. p. 120-130.

is paper reports the results of research conducted in 1973 and 1974 on the infiltration and osion rates of bare overburden piles and examines the influence of several soil variables on ese hydrologic characteristics. In spite of their relatively short existence, overburden les are potential sources of water quality degradation, greatly accelerated erosion, and eatly increased surface water runoff. In the final analysis, the potential hydrologic problems sociated with overburden piles are subject, almost totally, to the control of the mine operator.

418. Ford, Bacon and Davis Utah, Inc.
1977. Phase II, Title I engineering assessment of inactive uranium mill tailings, Fall City site, Falls City, Texas. 168 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-16.]

An engineering assessment was performed of the problems resulting from the existence of radioactive uranium mill tailings at Falls City, Tex. Services included taking soil samples, the performance of radiometric measurements sufficient to determine areas and volumes of tailings and other radium-contaminated materials, the evaluation of resulting radiation exposures of individuals and nearby populations, the investigation of site hydrology and meteorology, and the evaluation and costing of alternative corrective actions. Radon gas release from the 2.5 million tons of tailings at the Falls City site constitutes the most significant environmental impact. Windblown tailings, external gamma radiation, and localized contamination of surface waters are other environmental effects. The two alternative remedial action options presented include on-site and off-site cleanup, fencing, and hydrological monitoring, and, in addition, stabilization of pile 2 with 2 ft of cover material. The costs are $1.84 million for option I and $2.45 million for option II.

419. Ford, Bacon and Davis Utah, Inc.
1977. Phase II, Title I engineering assessment of inactive uranium mill tailings, Gree River site, Green River, Utah. 153 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-14.]

An engineering assessment was performed of the problems resulting from the existence of radioactive uranium mill tailings at the Green River site, Utah. Services included the preparation of topographic maps, the performance of core drillings and radiometric measurements sufficient to determine areas and volumes of tailings and other radium-contaminated materials, the evaluation of resulting radiation exposures of individuals and nearby populations, the investigation of site hydrology and meteorology, and the evaluation and costing of alternative corrective actions. Radon gas release from the 123 thousand tons of tailings at the Green River site constitutes the most significant environmental impact, although windblown tailings and externa gamma radiation are also factors. The three alternative actions presented are dike stabilizat fencing, on- and off-site decontamination and maintenance (option I); improvements in the stabilization cover and diking plus cleanup of the site and Browns Wash, and realignment of Browns Wash (option II); and addition of stabilization cover to a total of 2 ft, realignment c Browns Wash and placement of additional riprap, on-site cleanup and drainage improvements (option III). All options include remedial action at off-site structures. Cost estimates for the three options range from $700,000 to $926,000.

420. Ford, Bacon and Davis Utah, Inc.
1977. Engineering assessment of inactive uranium mill tailings, Gunnison site, Gunnisc Colo., Phase II, Title I. 237 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-12.]

An engineering assessment was performed of the problems resulting from the existence of radioactive uranium mill tailings at Gunnison, Colo. Services included the preparation of topographic measurements sufficient to determine areas and volumes of tailings and other radiu contaminated materials, the evaluation of resulting radiation exposures of individuals and nearby populations, the investigation of site hydrology and meteorology, and the evaluation an costing of alternative corrective actions. Radon gas release from the 0.5 million tons of tailings at the Gunnison site constitutes the most significant environmental impact, although windblown tailings and external gamma radiation are also factors. The nine alternative action presented range from millsite decontamination (option I), to adding various depths of stabiliz tion cover material (options II and III), to removal of the tailings to long-term storage site and decontamination of the present site (options IV through IX). Cost estimates for the nine options range from $480,000 to $5,890,000. Reprocessing the tailings for uranium does not appear to be economically attractive at present.

21. Ford, Bacon and Davis Utah, Inc.
1977. Engineering assessment of inactive uranium mill tailings, Maybell site, Maybell, Colo., Phase II, Title I. 255 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-11.]

n engineering assessment was performed of the problems resulting from the existence of radio-ctive uranium mill tailings at Maybell, Colo. The services included the preparation of topo-raphic maps, the performance of core drillings sufficient to determine areas and volumes of ailings and radiometric measurements to determine radium-contaminated materials, the evaluation f resulting radiation exposures of individuals and nearby populations, the investigation of ite hydrology and meteorology, and the evaluation and costing of alternative corrective actions. adon gas release from the 2.6 million tons of tailings at the Maybell site constitutes the ost significant environmental impact, although windblown tailings and external gamma radiation re also factors. The three alternative actions presented range from fencing and maintenance option I), to placing the tailings in an open-pit mine and adding 2 ft of stabilization cover aterial (option III). Cost estimates for the three options range from $250,000 to $4,520,000. eprocessing the tailings for uranium does not appear to be economically attractive at present.

22. Ford, Bacon and Davis Utah, Inc.
1977. Phase II, Title I engineering assessment of inactive uranium mill tailings, Mexican Hat site, Mexican Hat, Utah. 167 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-3.]

n engineering assessment of the problems resulting from the existence of radioactive uranium ill tailings at the Mexican Hat mill site in Utah is presented. Topographic maps, data on ore drillings and radiometric measurements sufficient to determine areas and volumes of tailings nd other radium-contaminated materials, the evaluation of resulting radiation exposures of ndividuals residing nearby, the investigation of site hydrology and meteorology, and the valuation and costing of alternative corrective actions are presented. Radon gas release from he 2.2 million tons of tailings on the site constitutes the most significant environmental mpact. The six alternative actions presented are directed towards restricting access to the ite, returning the windblown tailings to the piles and stabilizing the piles with cover material, nd consolidating the two piles into one pile and stabilizing with cover material. Fencing round the site or the tailings and the decontamination of mill buildings is included in all ptions. Costs of the options range from $370,000 to $4,390,000.

23. Ford, Bacon and Davis Utah, Inc.
1977. Phase II, Title I engineering assessment of inactive uranium mill tailings, Monument Valley site, Monument Valley, Ariz. 172 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-4.]

n engineering assessment was made of the problems resulting from the existence of radioactive ranium mill tailings at the Monument Valley mill site in Arizona. The services included the reparation of topographic maps, the performance of core drillings and radiometric measurements ufficient to determine areas and volumes of tailings and other radium-contaminated materials, e evaluation of resulting radiation exposures of individuals residing nearby, the investigation f site hydrology and meteorology, and the evaluation and costing of alternative corrective tions. Radon gas release from the tailings on the site constitutes the most significant vironmental impact, although windblown tailings and external gamma radiation are also factors. e sparse population and relatively low radiation levels yield minimal immediate environmental pact; hence, the two alternative actions presented are directed toward restricting access to e site and returning the windblown tailings to the pile and stabilizing the pile. Both tions include remedial action costs for off-site locations where tailings have been placed. st estimates for the two options are $585,000 and $1,165,000.

24. Ford, Bacon and Davis Utah, Inc.
1977. Engineering assessment of inactive uranium mill tailings, new and old Rifle sites, Rifle, Colorado, Phase II, Title I. 234 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-10.]

An engineering assessment was performed of the problems resulting from the existence of radio active uranium mill tailings at Rifle, Colorado. The services included the preparation of topographic maps, the performance of core drillings and radiometric measurements sufficient t determine areas and volumes of tailings and other radium-contaminated materials, the evaluati of resulting radiation exposures of individuals and nearby populations, the investigation of site hydrology and meteorology, and the evaluation and costing of alternative corrective acti Radon gas release from the 3.1 million tons of tailings at the two Rifle sites constitutes th most significant environmental impact. Windblown tailings, external gamma radiation, and localized contamination of surface waters are other environmental effects. The 15 alternativ remedial action options presented range from mill-site decontamination and off-site remedial action (options I and IV), to adding various depths of stabilization cover material (options II, V, VI, and VII), to removal of the tailings to long-term storage sites and decontaminatio of the present sites (options III and VIII through XV). Cost estimates for the first 14 opti range from $224,000 to $20,300,000. Option XV, estimated at $32,200,000, includes the cost f moving both Rifle tailings piles and the Grand Junction tailings pile to DeBeque for long-ter storage and site decontamination after removal of the piles. Reprocessing of the tailings fo uranium appears not to be economically attractive at present.

425. Ford, Bacon and Davis Utah, Inc.
1977. Phase II, Title I engineering assessment of inactive uranium mill tailings, Phillips/United Nuclear site, Ambrosia Lake, N.Mex. 151 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-13.]

An engineering assessment was performed of the problems resulting from the existence of radioactive uranium mill tailings at the Phillips/United Nuclear site at Ambrosia Lake, N.Mex. Services included the preparation of topographic maps, the performance of core drillings sufficient to determine areas and volumes of tailings, and radiometric measurements to determ radiumcontaminated materials, the evaluation of resulting radiation exposures of individuals a nearby populations, the investigation of site hydrology and meteorology, and the evaluation a cost of alternative corrective actions. Radon gas release from the 2.6 million tons of taili at the Phillips/United Nuclear site constitutes the most significant environmental impact, although windblown tailings and external gamma radiation are also factors. The estimated radiological health effects to the general population are considered to be minimal. The two alternative actions presented are: dike stabilization, fencing, and maintenance; and adding 2 ft of stabilization cover material. Both options include remedial action at off-site structu and on-site decontamination around the tailings pile. Cost estimates for the two options are $920,000 and $2,230,000, respectively.

426. Ford, Bacon and Davis Utah, Inc.
1977. Engineering assessment of inactive uranium mill tailings, Spook Site, Converse County, Wyo., Phase II, Title I. 142 p. Ford, Bacon and Davis Utah, Inc., Salt Lak City. [Available NTIS as GJT-15.]

An engineering assessment of the problems resulting from the existence of radioactive uranium mill tailings was performed at the Spook Site, Converse County, Wyo. Data are presented from soil, water, and other sample analyses, radiometric measurements to determine areas with radiu contaminated materials, the evaluation of resulting radiation exposures of individual and nearby populations, the investigation of site geology, hydrology, and meteorology, and the evaluation and cost of alternative corrective actions. Radon gas release from the 187,000 ton of tailings at the Spook Site constitutes the main environmental impact, which is negligible. The two alternative actions presented are better fencing of the site in its present state and placing tailings and contaminated on-site materials and soil in the open-pit mine and covering the resulting pile with 2 ft of overburden material. The cost estimates for the options are $82,000 and $142,000, respectively. Reprocessing the tailings for uranium at a nearby operati uranium mill is worthy of economic consideration at this time.

427. Ford, Bacon and Davis Utah, Inc.
1977. Summary of the Phase II, Title I engineering assessment of inactive uranium mill tailings, Tuba City site, Tuba City, Ariz. 51 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-5S.]

An engineering assessment was performed of the problems resulting from the existence of radioactive uranium mill tailings at the Tuba City mill site in Arizona. Services include the preparation of topographic maps, the performance of core drillings and radiometric measurements sufficient to determine areas and volumes of tailings and other radium-contaminated materials, the evaluation of resulting radiation exposures of individuals residing nearby, the investigation of site hydrology and meteorology, and the evaluation and cost of alternative corrective actions. Radon gas release from the tailings on the site constitutes the most significant environmental impact to the inhabited area near the site.

428. Ford, Bacon and Davis Utah, Inc.
1977. Phase II, Title I engineering assessment of radioactive sands and residues, Lowman site, Lowman, Idaho. 133 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-17.]

An engineering assessment was performed of the problems resulting from the existence of radioactive uranium sand residues at the Lowman, Idaho, site. Services included the preparation of topographic maps, the performance of core drillings and radiometric measurements sufficient to determine areas and volumes of tailings and other radium-contaminated materials, the evaluation of resulting investigations of site hydrology and meteorology, and the evaluation and cost of alternative corrective actions. Radon gas release from the 90,000 tons of sand residues at the Lowman site constitutes the most significant environmental impact, although external gamma radiation is also a factor. The two alternative actions presented are dike construction, fencing, and maintenance (option I); and consolidation of the piles, addition of a 2-ft-thick stabilization cover, and on-site cleanup (option II). Both options include remedial action at off-site structures. Cost estimates for the two options are $393,000 and $590,000.

429. Franklin, J. C., T. O. Meyer, and R. C. Bates.
1977. Barriers for radon in uranium mines. 29 p. Spokane Mining Res. Center, Bur. Mines, Spokane, Wash. [Available NTIS as PB-277 331/5ST.]

Water-based epoxy sealants were examined during a 2-year period to determine their effectiveness as barriers to radon release in uranium mines. Radon emanation rates from uranium ore samples were monitored for extended periods in the laboratory before and after sealant application. Reduction of radon flux due to the coating of lab samples was approximately 80 percent. Test chambers in a dormant uranium mine were monitored to determine both short- and long-term barrier effectiveness. These field studies of the sealants indicated reductions greater than 50 percent relatively soon after application and nearly 75 percent more than 1 year later. An unexpected complication to early monitoring in the form of a large radon emanation increase, believed due to added moisture, is discussed.

430. General Accounting Office.
1978. The uranium mill tailings cleanup: Federal leadership at last. 60 p. Energy and Minerals Div., General Accounting Off., Washington, D.C. [Available NTIS as PB-283 064/4ST.]

The Department of Energy has proposed legislation that would allow it to enter into cooperative greements with various States to clean up residual radioactive materials--commonly called uranium mill tailings--at 22 inactive uranium mills. About 25 million tons of mill tailings have accumulated at these sites since the 1940's. GAO analyzed the need for, and adequacy of, he proposed legislation and recommends that the cleanup program be endorsed. While the Federal Government has no apparent legal responsibility for such a cleanup, it does have a moral responsibility since the mills primarily produced uranium for Federal programs. Further, it is the only organization able to undertake such a cleanup program on a comprehensive basis. GAO also uggests several areas where the proposed legislation could be strengthened.

31. Girucky, F. E.
1972. New tailing dam construction at White Pine. In Tailings disposal today [First Int. Symp., Tucson, Ariz., Oct. 31-Nov. 3, Proc.]. p. 743-761. C. L. Aplin and G. O. Argall, eds. 860 p. Miller Freeman Publishers, Inc., San Francisco, Calif.

432. Goldsmith, W. A., F. F. Haywood, and R. W. Leggett.
1978. Transport of radon which diffuses from uranium mill tailings (summary paper). Int. Symp. on the Natural Radiation Environment III [Houston, Tex., Apr. 23-28, 1978]. p. 242-245.

433. Hagstrom, G. R., J. L. Stroehlein, and J. Ryan.
1976. Sulphuric acid + mining residue = promising iron fertilizer material. J. Sulph Inst. 12(2):12-15.

434. Harvey, S., and T. Weaver.
1978. The annual cycle of soil-water availability on coal spoil, southeastern Montana. Proc. Mont. Acad. Sci. 38:85-87.

435. Hasebe, S., H. Sato, I. Matsuoka, and others.
1975. Slime treatment by flotation process in limestone mine. Technol. Rep. Iwate Univ. 10:35-44.

In a limestone mine, a large amount of slime is washed off in order to remove impurities such as clay minerals. A fine sized calcite is consequently wasted, and freight for carrying the slime to reclaim land is expensive. The separation of calcite from the slime by the flotation process, using sodium oleate as a collector, is investigated. A satisfactory flotation of calcite from the slime requires great amounts of sodium oleate, because sodium oleate is consu by clay minerals. But, the amounts of sodium oleate required are reduced to half by adding suitable amounts of sodium silicate. After rougher and cleaner flotation, the concentrate containing more than 97 percent calcite is obtained with 70 percent recovery; thereby the amount of slime to be reclaimed is reduced to 40 percent.

436. Havens, R., and K. C. Dean.
1969. Chemical stabilization of the uranium tailings at Tuba City, Arizona. U.S. Bur. Mines Rep. of Investigations 7288, 12 p. Washington, D.C.

437. Heley, W.
1974. Processed shale disposal for a commercial oil shale operation. Mining Congr. J. 26(5):25-29.

438. Hersman, L. E.
1977. Microbial activity in strip mine spoils. Ph.D. diss. Mont. State Univ., Bozema 86 p.

439. International Energy Agency.
1976. Management of wastes from the mining and milling of uranium and thorium ores. Int. Energy Agency Safety Serv. 44:57.

440. Jackson, G., and S. Ware.
1977. The feasiblity of utilizing solid wastes for building materials. Executive summary. 96 p. Ebon Research Systems, Silver Springs, Md. [Available NTIS as PB-271 007/7ST.]

This report focuses on two phases of a suggested four-phase study to evaluate the technologica and commercial possibilities of waste-derived composites. The first phase involved a joint an comprehensive literature search to identify wastes with potential as building materials. Limited laboratory studies were conducted on composite materials produced from the more promis wastes investigated. A composite material was defined as a product containing a filler, a reinforcement, and a matrix. Various characteristics were considered desirable for the filler the reinforcement, and the matrix. The wastes identified through the literature search were evaluated against these desirable properties. A listing of the evaluative criteria and the rating system used is presented. Filler materials reviewed included fly ash, crushed glass, phosphate slimes, silicate waste, shredded refuse, waste plastic, wood bark, rice hulls, tacon red mud, coal waste, foundry ash, and sawdust. Reinforcement materials reviewed included carbonized lignin, bagasse, wheat straw, bark, kenaf, bamboo, wood chips, cotton waste, and glass roving. Sewage sludge, sawdust, rice hulls, plastic scrap, and waste glass also received attention as reinforcements.

441. Jennett, J. C., and G. B. Wixson.
1972. Problems in lead mining waste control. Water Pollution Contr. Fed. J. 44(11):2103-2110.

442. Jeppson, R. W., R. W. Hill, and C. E. Israelsen.
1974. Slope stability of overburden spoil dumps from surface phosphate mines in southeastern Idaho. 69 p. Water Res. Lab., Utah State Univ., Logan.

443. Kenahan, C. B., R. S. Kaplan, J. Dunham, and others.
1973. Bureau of Mines research program on recycling and disposal of mineral-, metal-, and energy-based wastes. 60 p. U.S. Bur. Mines, Washington, D.C. [Available NTIS as PB-227 476/9.]

A summary of Bureau of Mines research on utilization and disposal of solid wastes is presented, accompanied by an extensive bibliography of related publications. The Bureau's Solid Waste and Materials Recycling Program is directed toward four main areas of research, development, and demonstrations: (1) extraction of mineral, metal, and energy values from urban refuse; (2) upgrading and recycling of automotive and related ferrous and nonferrous scrap; (3) utilization and stabilization of mine, mill, and smelter wastes; and (4) recovery and reuse of values from industrial waste products.

444. Kessick, M. A.
1978. Clay slimes from the extraction of Alberta oil sands, Florida phosphate matrix and other mined deposits. Can. Inst. Mining and Metall. Bull. 71(790):80-88.

445. Knopp, C.
1978. Infiltration erosion on phosphate mine overburden spoils. Master's thesis. Utah State Univ., Logan. 65 p.

This study was to determine if the sedimentary strata exhumed as phosphate strip mine overburden, and subsequently used as surface fill for waste dumps, exhibited different infiltration and erosion rates. Three different soils, as delineated by color, were present. Based upon analysis of variance tests, the infiltration and erosion rates for the three soils were different. Modulus of ruptures accounted for 56 percent of the variability in soil erosion, and provided an easy and effective means of correlating different sedimentary strata as to their relative erodibilities.

446. Lamont, W. E., and others.
1975. Characterization studies of Florida phosphate slimes. U.S. Bur. Mines, Rep. of Investigations 8089, 28 p. Washington, D.C.

447. Levins, D. M., R. K. Ryand, and K. R. Strong.
1978. Leaching of radium from uranium tailings. In Proc. Seminar on Management, Stabilization and Environmental Impact of Uranium Mill Tailings [Albuquerque, N.Mex., July 24-28, 1978]. p. 271-287. Organization for Econ. Coop. and Develop., Nuclear Energy Agency, Albuquerque, N.Mex., and Paris, France.

448. Ludeke, K. L.
1973. Soil properties of materials in copper mine tailing dikes. Mining Congr. J. 59(8):30-36.

449. Lush, D., J. Brown, J. R. Fletcher, and others.
1978. An assessment of the long-term interaction of uranium tailings with the natural environment. In Proc., Seminar on Management, Stabilization and Environmental Impact of Uranium Mill Tailings [Albuquerque, N.Mex., July 24-28, 1978]. p. 373-398. Organization for Econ. Coop. and Develop., Nuclear Energy Agency, Albuquerque, N.Mex., and Paris, France.

450. MacBeth, P. J., C. M. Jensen, V. C. Rogers, and others.
1978. Laboratory research on tailings stabilization methods and their effectiveness in radiation containment. U.S. Dep. Energy, Grand Junction, Colo., Rep. GJT-21, 117 p.

451. Mace, A. C., K. N. Brooks, J. P. Borovsky, and others.
1976. Feasibility of using iron ore overburden material as a media for disposal of secondary sewage effluent in northeastern Minnesota. 57 p. Water Resour. Res. Cent., Minn. Univ., Minneapolis. [Available NTIS as PB-281 307/9ST.]

The establishment and growth of municipalities and the extent of open-pit mining in the Mesabi Iron Range of northeastern Minnesota have created conflicts between economic development and environmental concerns. The discharge of secondary treated sewage effluent into streams and lakes by the numerous small Iron Range municipalities contributes to the eutrophication proble even though water quality standards may be achieved. The elimination of such nutrient polluti by means of tertiary treatment facilities would be, for the most part, economically prohibitiv for these small communities. The disposal of treated sewage effluent on land, however, could provide a more feasible alternative. The purpose of this study was to investigate the feasibilit of sprinkler irrigation of sewage effluent on iron-ore overburden deposits as a means of allev-ating water quality problems. Specific objectives were to: (1) evaluate the efficiency of irn-ore overburden material to renovate secondary sewage effluent and thereby reduce the levels of nutrients entering receiving waters, and (2) evaluate amelioration characteristics of secondar sewage effluent to increase the establishment of grass, wildlife forage, and forest species on overburden sites.

452. Martin, J. B., and H. J. Miller.
1978. Generic environmental impact statement on U.S. uranium milling industry. In Proc., Seminar on Management, Stabilization and Environmental Impact of Uranium Mill Tailings [Albuquerque, N.Mex., July 24-28, 1978]. p. 453-469. Organization for Econ. Coop. and Develop., Nuclear Energy Agency, Albuquerque, N.Mex., and Paris, France.

453. May, J. T., H. H. Johnson, H. F. Perkins, and others.
1973. Some characteristics of spoil material from kaolin clay strip mining. In Ecolog and reclamation of devastated land. [Int. Symp. on Ecol. and Reveg. of Drastically Disturbed Areas], vol. 1. p. 3-14. R. S. Hutnik and G. Davis, eds. Gordon & Breac New York.

454. Mining Magazine.
1975. Florida phosphate mines test innovations in transport and tailings disposal. Mining Mag. (October):281-283.

455. Mink, L. L., R. E. Williams, and A. T. Wallace.
1972. Effect of early day mining operations on present day water quality. Ground Wate 10(1):17-26.

456. Moffett, D.
1976. The disposal of solid wastes and liquid effluents from the milling of uranium ores. Can. Centre for Mineral and Energy Technology, Minerals Res. Prog., Mining Res. Lab., CANMET Rep. 76-19.

457. Moschopedis, S. E., and D. L. Mitchell.
1974. Sulfomethylated humic acid products as soil conditioners and fertilizers for the restoration of the Athbasca oil sand mining area. Can. For. Serv., Infor. Rep. NOR-X 116:152-161. North. For. Res. Cent., Edmonton, Alta.

458. Nebgen, J. W., J. G. Edwards, and D. F. Weatherman.
1976. Use of waste sulfate for remedial treatment of soils, vol. I. Discussion of results. 217 p. Midwest Res. Inst., Kansas City, Mo. [Available NTIS as PB-278 140/9ST.]

The effects of waste sulfate (phosphogypsum from fertilizer manufacture, fuel gas desulfurization solids, and neutralized acid mine drainage solids) on physical and strength properties of soils have been studied. Waste sulfate alone has little effect on soil strengths. However, if it is used in combination with lime, higher strengths can be achieved with waste sulfate/lime than can be obtained with equivalent lime treatment because of soil-sulfate-lime reactions. Fly ash can be used with waste sulfate/lime mixtures to improve strengths further. Cement kiln dust has been shown to be an effective substitute for lime as a soil stabilizer. The report is presented in two volumes. Volume I, Discussion of Results, describes the experimental work and contains the interpretation of data and conclusions and recommendations.

459. Nuclear Regulatory Commission.
1977. Branch position - uranium mill tailings management, Fuel Processing and Fabrication Branch [May 13, 1977]. Nuclear Regulatory Commission, Washington, D.C.

460. Parekh, B. K., and W. M. Goldberger.
1976. An assessment of technology for possible utilization of Bayer Process muds. 155 p. Battelle Columbus Labs., Ohio. [Available NTIS as PB-266 678/2ST.]

The program comprised reviews of technical literature published from 1940 on subjects related to technology of processing bauxite, the dewatering and impoundment of the mud residues and their possible utilization. Mud samples were received from the domestic alumina plants for characterization experiments and dewatering studies at Battelle and at the laboratories of the Dow Chemical Company in Midland, Mich. It was concluded from the study that there is no possibility for utilization of the muds that could significantly affect the need for impoundment within the near term. Improved mud dewatering and methods of impoundment appear possible to develop, however, and a program of joint industry-government investigations of the possible beneficiation of the muds into a raw material supplement in iron making and the possible use of mud as an absorbent in pollution abatement processes are also recommended.

461. Pigott, P. G., E. G. Valdex, and K. C. Dean.
1971. Dry-pressed building bricks from copper mill tailings. U.S. Bur. Mines, Rep. of Investigations 7537, 13 p. Washington, D.C.

462. Rouston, R. C., and others.
1977. Developments of chemical reactions, stability and transport model of oil shale process wastes in soil. In Pacific Northwest Annual Report for 1976 to the ERDA Assistant Administrator for Environment and Safety. p. 2.9-2.11. B. E. Vaughan, ed.

63. Scarano, R. A., and J. J. Linehan.
1978. Current U.S. Nuclear Regulatory Commission licensing review process: uranium mill tailings management. In Proc., Seminar on Management, Stabilization and Environmental Impact of Uranium Mill Tailings [Albuquerque, N.Mex., July 24-28, 1978]. p. 407-427. Organization for Econ. Coop. and Develop., Nuclear Energy Agency, Albuquerque, N.Mex., and Paris, France.

64. Schmidtke, N. W., D. Averill, D. N. Bryant, and others.
1978. Removal of 226 Ra from tailings pond effluents and stabilization of uranium mine tailings-bench and pilot plant studies. In Proc., Seminar on Management, Stabilization and Environmental Impact of Uranium Mill Tailings [Albuquerque, N.Mex., July 24-28, 1978]. p. 299-317. Organization for Econ. Coop. and Develop., Nuclear Energy Agency, Albuquerque, N.Mex., and Paris, France.

65. Schuman, G. E, W. A. Berg, and J. F. Power.
1976. Management of mine wastes in the western United States. In Land application of waste materials. p. 180-194. Soil Conserv. Soc. Am., Ankeny, Iowa. 313 p.

66. Shetron, S. G., and R. Rittler.
1973. Evaporation of water from reclaimed copper stamp sands. Mich. Tech. Univ., L'anse, Res. Note 8, 5 p.

Potential water losses from porous, structureless, sandy copper stamp sands by evaporation averaged 0.41 inch per day in the surface 6 inches for June, July, and August. Greatest poten loss was found to be 0.78 inch per day and lowest loss was 0.04 inch per day. Incoming weekly solar radiation averaged 0.890 Langleys. Available water (1/3-15 bar) storage capacity of the stamp sands in the upper 6 inches amounts to 1.65 inches of water.

467. Sorensen, D. L., M. A. Anderson, W. A. Kneib, and others.
1975. Establishment of microbial populations in sterile mine spoils and overburden. I Development of microbial bioassay procedures. 40 p. Water Res. Lab., Utah State Univ., Logan.

Chemical and microbial analyses of overburden and topsoiling material (forest subsoil) from th Blackbird Mine near Salmon, Idaho, showed that microbial biomass and diversity were minimal. Bioassay methods were developed to assess the means of changing conditions so that stable and diverse microbial communities typical of fertile, productive soils could be established. Results of laboratory studies showed that the limiting factors for soil algal growth were, in order of importance: water availability, pH, and phosphorus. Other nutrients and heavy metal immobilization by pH adjustments were altered sufficiently by the above three parameters to allow considerable microbial productivity. A simple and convenient short-term bioassay techni was developed for use on soil systems.

468. Sorensen, D. L., W. A. Kneib, and D. B. Procella.
1979. Determination of sulfide in pyritic soils and minerals with a sulfide ion electr Anal. Chem. 51:1870-1872.

By combining sulfide ion selective electrode methodology with a method which releases sulfide ion from mineral matrices, a method has been developed which allows analysis of sulfide-sulfur in rocks and minerals without concern for interferences common to gravimetric sulfate analysis The method has demonstrated good precision and accuracy in samples ranging from more than 50 t less than 0.01 percent sulfide-sulfur (relative standard deviation, 13 percent). Reliable sensitivity seems to be limited to about 0.03 percent sulfide-sulfur in a 150 mg sample. Sulfate-sulfur is reduced to sulfide-sulfur in analysis, and must be removed from sulfate-containing samples to avoid interference.

469. Sorensen, D. L., W. A. Kneib, D. B. Porcella, and others.
1980. Determining the lime requirement for Blackbird Mine spoil. J. Environ. Qual. 9:162-166.

The production of acid from oxidation of pyritic inclusions in mineral mine overburden prevent the revegetation of the overburden. A total lime requirement must be determined and met in order to control existing acidity and to prevent reacidification as oxidation of pyritic mater in the overburden continues.

470. Spendlove, M. J.
1977. Bureau of Mines research on resource recovery. Reclamation, utilization, dispos and stabilization. 112 p. U.S. Bur. Mines, College Park, Md. [Available NTIS as PB-272 921/8ST.]

This report reviews in annotated form the Bureau of Mines research and related studies in the fields of resource recovery, land restoration, reclamation and stabilization, and utilization and/or disposal of postconsumer goods and industrial wastes. Numerous typical examples of research are discussed in each sector of the U.S. materials supply--utilization--disposal system. Included are raw materials extraction, raw material beneficiation, bulk materials processing manufacturing, secondary materials, and postconsumer materials utilization and disposal. Discussions are supported with appropriate charts, tables, diagrams, and photograph illustrations. Each section includes extensive lists of other related references.

471. Stanczyk, M. H., I. L. Feld, and E. W. Collins.
1971. Dewatering Florida phosphate pebble rock slime by freezing techniques. 25 p. U.S. Bur. Mines, Washington, D.C. [Available NTIS as PB-200-702.]

Freezing to dewater typical Florida phosphate rock slime as demonstrated in laboratory tests appeared to have potential commerical use because of indicated moderate energy requirements, good compaction of dewatered solids, and effective recovery of usable water. After freezing, thawing, decanting, and filtering, batch freezing of gallon-size 13.7 percent solids slime samples yielded 42 percent solids products. Cationic amine, used as a process additive, yielded 46.8 percent solids product with significant filter area reduction. Semicontinuous eight-stage freezing tests also produced thickened slimes. Cooling and freezing 13.7 percent solids slime from 50° to -10°C required removal of 183 Btu per pound of slime; Carnot cycle calculations indicate that the theoretical minimum energy to transfer this heat was 27.8 Btu per pound. To produce 1 ton of 44 percent solids slime from 13.7 percent solids slime, the calculated theoretical energy required for cooling and freezing was 52.3 kilowatt-hours. During the research, heat capacity and heat of fusion data were determined for the slime at various percent solids.

472. Striffler, W. D., I. F. Wymore, and W. A. Berg.
1974. Chracteristics of spent shale which influence water quality, sedimentation and plant growth. In Surface rehabilitation of land disturbances resulting from oil shale development, executive summary. p. 40-47. C. W. Cook, ed. Colo. State Univ., Fort Collins, Environ. Resour. Cent., Infor. Series 11, 56 p.

473. Terichow, O., G. V. Sullivan, and E. K. Landis.
1975. Electrophoretic studies of a Florida phosphate slime. U.S. Bur. Mines, Rep. of Investigations 8028, 17 p. Washington, D.C.

Electrophoretic mobility measurements were made by the Bureau of Mines on samples of a Florida phosphate slime to determine the optimum conditions of coagulation and settling in an aluminum sulfate solution. Addition of anthracite to promote mutual coagulation demonstrated the practicability of heterocoagulation by reduction of the repulsive effect of double layers. By proper selection of the electrolyte and its concentration, the reduction of the double layers to a net zero point of charge causes the predominance of Van der Waals' forces of attraction leading to the coagulation and rapid settling of both particle systems, as is predicted by the Derjaguin-Landua-Verway-Overbeek theory of colloidal stability. Confirmation was found in the microfiltration tests where a modified Carman equation was applied to evaluate the specific filter bed resistance.

474. Toland, G. C.
1971. A case history: design of a gypsum tailing pond. Mining Eng. 23(12):57-58.

475. U.S. Bureau of Mines and ITT Research Institute.
1970. Proc., Second Mineral Waste Utilization Symp., held March 18-19, 1970, Chicago, Ill. 373 p.

Symposium focuses on current efforts to utilize a wide spectrum of waste materials, ranging from abandoned automobiles to steel mill slags, paper mill sludges, mining tailings, and municipal refuse. More than 40 papers and panel discussions were published and those of particular interest include: ash utilization techniques; a profile of the nonferrous secondary metals industry; mineral content of municipal refuse; high temperature incineration; and utilization of waste glass. Selected papers are indexed separately.

476. Wallace, A., and others.
1976. Use of waste pyrites from mine operations on highly calcareous soil. Commun. Soil Sci. and Plant Anal. 7(1):57-60.

477. Weston, R. F.
1971. Concept evaluation report, taconite tailings disposal, Reserve Mining Company, Silver Bay, Minnesota. 159 p. R. F. Weston, Inc., West Chester, Penn. [Available NTIS as PB-259 510/6ST.]

The Office of Water Programs of the Environmental Protection Agency retained Roy F. Weston to develop conceptual methods for treating and disposing of the taconite wastes and to conduct an independent evaluation of feasible wastewater treatment and disposal alternatives. The sectio cover the following: the major issues developed by previous studies of tailings discharges to Lake Superior; technical review of previous proposals for treatment and disposal of taconite tailings; discussion of Roy F. Weston's process investigation and tailings reuse; concept design of various alternatives for tailings processing and disposal; and the economic and financial impact on Reserve Mining and on the State of Minnesota of implementation of various proposals for taconite tailings disposal.

478. Weston, R. F., and M. L. Woldman.
1971. Taconite tailings disposal, Reserve Mining Company, Silver Bay, Minnesota. 179 p. R. F. Weston, Inc., West Chester, Penn. [Available NTIS as PB 253 346/1ST.]

The overall objective of this assignment is to develop minimum cost solutions consistent with the conference guidelines for protecting the environment in general and for conformance to the Federally approved "Specific Standards of Quality and Purity for Lake Superior" (contained in WPC 15) in particular. The limits or ranges of the various contaminant substances specified i "Specific Standards of Quality and Purity for Lake Superior" are shown. It should be noted that the assignment essentially was a presentation of an impartial evaluation rather than development of specific conclusions and recommendations. The sections cover the following: the major issues developed by previous studies of tailings discharges to Lake Superior, techni review of previous proposals for treatment and disposal of taconite tailings, discussion of Ro F. Weston's process investigation and tailings reuse, concept design of various alternatives for tailings processing and disposal, and the economic and financial impact on Reserve Mining and on the State of Minnesota of implementation of various proposals for taconite tailings disposal.

479. Williams, R. E., C. D. Kealy, and L. L. Mink.
1973. Effects and prevention of leakage from mine tailings ponds. Soc. Mining Eng. Am Inst. Mining, Metallurgical and Petroleum Eng., Trans. 254(3):212-216.

480. World Mining.
1975. Kaiser drains red mud to make land fill. World Mining 28(3):53.

481. Yang, D. C.
1977. Disposal of mineral wastes and recovery of water from oxidized taconite slime tailings. Inst. Min. Res., Mich. Tech. Univ., Houghton. 140 p. [Available NTIS as PB-267 714/4ST.]

The report describes research to evaluate the flocculation, settling, and disposal of slimes and tailings from the beneficiation of oxidized taconite and to determine the effects of recyc water on the beneficiation process. The flocculation-desliming process was affected by pH, amine concentration, and water hardness. There were no deleterious effects from recycling water.

H. Effects on Flora

Citations in section H deal primarily with the effects of surface mining on vegetation. Citations on plants used for revegetation are included in section M. See also "Flora" in the index.

482. Alloway, B. J., and B. E. Davies.
1971. Heavy metal content of plants growing on soils contaminated by lead mining. J. Agric. Sci. (London) 76(2):312-323.

483. Amaugo, G. O.
1973. Effects of four soil materials in copper mine tailing disposal berms of total fiber, total protein, and amino acid content in pasture forage from barley. Master's thesis. Univ. Ariz., Tucson. 31 p.

484. Antonovics, J.
1972. Population dynamics of the grass *Anthoxanthum odoratum* on a zinc mine. J. Ecol. 60(2):351-365.

485. Berg, W. A., and W. G. Vogel.
1968. Manganese toxicity of legumes seeded in Kentucky strip-mine spoils. USDA For. Serv. Res. Pap. NE-119, 12 p. Northeast For. Exp. Stn., Broomall, Penn.

The occurrence of manganese toxicity was studied on six legume species grown in 46 different acid strip-mine spoils from Kentucky. This toxicity was characterized by a distinct chlorosis on the leaf margins that was readily seen on young leaves of all the species except *Kobe lespedeza*. Soil pH was useful in predicting Mn toxicity on the legumes; water soluble Mn extracted from the spoils was not. Korean and bicolor lespedeza seedlings were susceptible to Mn toxicity on spoils with pH below the range of 5.0 to 5.5. *Sericea lespedeza* in the seedling stage was also susceptible below this pH range, but on some spoils it outgrew the early toxicity symptoms. *Kobe lespedeza*, birdsfoot trefoil, and black locust did not show Mn toxicity symptoms on most spoils with pH above 4.5.

486. Cox, R. M., D. A. Thruman, and M. Brett.
1976. Some properties of the soluble acid phosphates of roots of zinc-tolerant and non-tolerant clones of *Anthoxanthum odoratum* growing near zinc and lead mines in Wales. New Phytol. 77(3):547-552.

487. Crundwell, A.
1976. *Ditrichum plumbicola*, a new species from lead-mine waste. J. Bryol. 9(2):167-169.

488. Fuller, W. H., and K. Lanspa.
1975. Uptake of iron and copper by sorghum from mine tailings. J. Environ. Qual. 4(3):417-422.

489. Hemphill, D. D., and J. P. Pierce.
1974. Accumulation of lead and other heavy metals by vegetation in the vicinity of lead smelters and mines and mills in southeastern Missouri. In Trace contamination in the environment [Proc. of the Second NSF-RANN Conf.]. p. 324-332.

490. Ireland, M. P., and R. J. Wooton.
1976. Variation in the lead, zinc, and calcium content of *Dendrobaena rubida (Oligochaeta)* in a base metal mining area. Environ. Pollution 10(3):201-208.

491. Johnston, W. R., and J. Proctor.
1977. A comparative study of metal levels in plants from two contrasting lead-mine sites. Plant Soil 46(1):251-257.

492. Lefebvre, C.
1970. Self-fertility in maritime and zinc mine populations of *Armeria maritima* (Mill.) Wild. Evolution 24(3):571-577.

493. Rascio, N.
1977. Metal accumulation by some plants growing on zinc-mine deposits. Oikos 29(2):25 253.

494. Takijima, Y., and F. Katsumi.
1973. Cadmium contamination of soils and rice plants caused by zinc mining. Soil Sci. and Plant Nutrition 19(1):29-38.

495. Tunney, H., G. A. Fleming, A. N. O'Sullivan, and others.
1972. Effects of lead-mine concentrates on lead content of ryegrass and pasture herbag Irish J. Agric. Res. 11(1):85-92.

496. Wong, M. H., and F. Y. Tam.
1977. Soil and vegetation contamination by iron-ore tailings. Environ. Pollution 14(4):241-254.

497. Zwinger, A. H., and B. E. Willard.
1972. Land above the trees: a guide to American alpine tundra. 489 p. Harper & Row, New York.

I. Effects on Fauna

Citations in section I deal with the effects of surface mining on fish, wildlife, and domestic animals. Citations include those that are baseline data and inventories and those that describe the actual impacts on animals and habitat.

498. Blum, J. R.
1975. Oil shale and wildlife: what's it all about? In Environmental Oil Shale Symposium [Oct. 9-10] Proc. p. 147-152. J. D. Gary, ed. Colo. Sch. Mines, Quarterly 70(4). 244 p.

499. Catchpole, C. K., and C. F. Tydeman.
1975. Gravel pits as new wetland habitats for the conservation of breeding bird communities. Biol. Conserv. 8(1):47-59.

500. Dollahite, J. W., L. D. Rowe, L. M. Cook, and others.
1972. Copper deficiency and molybdenosis intoxication associated with grazing near a uranium mine. Southwest Vet. 26(1):47-50.

501. Egan, D. A., and J. O'Cuill.
1970. Cumulative lead poisoning in horses in a mining area contaminated with galena. Vet. Rec. 86(25):736-738.

502. Frischknecht, N. C.
1978. Use of shrubs for mined land reclamation and wildlife habitat. Reprinted from Proc. of Workshop on Reclamation for Wildlife Habitat. 14 p. Ecology Consultants, Inc., Fort Collins, Colo. USDA For. Serv., Intermt. For. and Range Exp. Stn., Ogden, Utah.

503. Institute of Land Rehabilitation.
1978. Rehabilitation of western wildlife habitat: a review. 237 p. Western Energy and Land Use Team, Off. Biol. Serv., U.S. Fish and Wildlife Serv., Fort Collins, Colo. [Available NTIS as PB-289-049 or GPO as 024-010-00513-1.]

504. Kuck, L.
1978. Southeast Idaho big game studies: I) Status and distribution of moose, elk, and mule deer in southeastern Idaho; II) phosphate mining impacts on big game; III) minimizing mining impacts on big game. Idaho Dep. Fish and Game, Proj. W-160-R-5, 139 p.

505. Layne, J. N.
1977. Fish and wildlife inventory of the seven-county region included in the central Florida phosphate industry areawide environmental impact study, vol. III, appendices A-G. 141 p. Am. Mus. Nat. Hist., Archbold Biol. Stn., Lake Placid, Fla. [Available NTIS as PB-278 458/5GA.]

This report is concerned with the potential impacts of phosphate mining on the fish and wildlife resources of the seven-county area (Charlotte, DeSoto, Hardee, Hillsborough, Polk, Manatee, Sarasota) of central Florida, where the phosphate industry in the State is presently concentrated, and where future expansion will occur. The objectives were to compile available data on the fish and wildlife resources in the region, including information on their distribution, habitat, and population levels; assess the direct and indirect impacts of phosphate mining on fauna; and recommend methods of mining or reclamation to minimize adverse effects on fish and wildlife.

506. Layne, J. N., J. A. Stallcup, G. E. Woolfenden, and others.
1977. Fish and wildlife inventory of the seven county region included in the central Florida phosphate industry areawide environmental impact study, vol. I. 656 p. Am. Mus. Nat. Hist., Archbold Biol. Stn., Lake Placid, Fla. [Available NTIS as PB-278 456/9GA.]

This report is concerned with the potential impacts of phosphate mining on the fish and wildlife resources of the seven-county area (Charlotte, DeSoto, Hardee, Hillsborough, Polk, Manatee, Sarasota) of central Florida, where the phosphate industry in the State is presently concentrated, and where future expansion will occur. The objectives were to compile availabl data on the fish and wildlife resources in the region, including information on their distrib tion, habitat, and population levels; assess the direct and indirect impacts of phosphate mining on fauna; and recommend methods of mining reclamation to minimize adverse effects on fish and wildlife.

507. Layne, J. N., J. A. Stallcup, G. E. Woolfenden, and others.
1977. Fish and wildlife inventory of the seven-county region included in the central Florida phosphate industry areawide environmental impact study, vol. II. 640 p. Am. Mus. Nat. Hist., Archbold Biol. Stn., Lake Placid, Fla. [Available NTIS as PB-278 457/7ST.]

This report is concerned with the potential impacts of phosphate mining on the fish and wildlife resources of the seven-county area (Charlotte, DeSoto, Hardee, Hillsborough, Polk, Manatee, Sarasota) of central Florida, where the phosphate industry in the State is presently concentrated, and where future expansion will occur. The objectives were to compile availabl data on the fish and wildlife resources in the region, including information on their distrib tion, habitat, and population levels; assess the direct and indirect impacts of phosphate mining on fauna; and recommend methods of mining or reclamation to minimize adverse effects o fish and wildlife.

508. Lefebvre, C.
1976. Breeding system and population structure of *Armeria maritima* (Mill.) Willd. on zinc-lead mine. New Phytol. 77(1):187-192.

509. National Fish and Wildlife Laboratory.
1978. Osceola National Forest phosphate extraction and processing. 427 p. Natl. Fish and Wildl. Lab., Gainesville, Fla. [Available NTIS as PB-283 444/8ST.]

The report discusses habitat requirements and status in the Osceola National Forest of all wildlife species listed as endangered, threatened, rare, special concern, or status undetermi by the U.S. Fish and Wildlife Service, the State of Florida, or the Florida Committee on Rare and Endangered Plants and Animals. Distribution maps for each species confirmed from the Osceola National Forest are provided and wildlife habitats are described and mapped. Predict impacts are based on comparisons with an active phosphate mine located in nearby Hamilton County, Fla. The report includes suggested mitigation and reclamation measures for all listed species, except those on the Federal list. This latter group will be addressed by the Office of Endangered Species, U.S. Fish and Wildlife Service.

510. Rafaill, B. L., and W. G. Vogel.
1978. A guide for revegetating surface mined lands for wildlife in eastern Kentucky and West Virginia. U.S. Dep. Interior, Fish and Wildlife Serv., Biol. Serv. Prog. FWS/OBS-78/84, 84 p.

This guide is a handbook to aid land managers in revegetating surface mined land areas for wildlife. The vegetation section included suitable species; planting and seeding methods (equipment needed, seedbed preparation); spoil amendments; and planting patterns beneficial t wildlife. The wildlife section includes habitat requirements for selected species.

511. Roberts, R. D., M. S. Johnson, and M. Hutton.
1978. Lead contamination of small mammals from abandoned metalliferous mines. Enviro Pollution 15(1):61-69.

512. Rogers, G. E.
1974. Oil shale development will affect wildlife. Colo. Outdoors 23(6):1-4.

13. Samuel, D. E., J. R. Stauffer, C. H. Hocutt, and others.
1978. Surface mining and fish/wildlife needs in the eastern United States [Proc. of a Symp., W.V. Univ.] U.S. Dep. Interior, Fish and Wildlife Serv., Biol. Serv. Prog. FWS/OBS-78/81, 386 p.

he symposium explored the relationships between mining and fish and wildlife. Sections nclude: lands (habitat) unsuitable for mining; planning to meet fish and wildlife needs; ethods and techniques for impact assessment; mining effects on water quality and aquatic ife; mining effects on terrestrial wildlife; reclamation techniques; wildlife utilization of ined lands; and opportunities for wildlife management on mined lands.

14. Shaid, T. A., and R. L. Linder.
1978. Nongame bird habitat associated with haul roads and surface mining for bentonite clay. S.Dak. Coop. Wildl. Res. Unit Quar. Rep. 15:10-12.

15. Spaulding, W. M., and R. D. Ogden.
1968. Effects of surface mining on the fish and wildlife resources of the United States. Bur. Sport Fish and Wildl. Resour. Publ. 68, 51 p.

ata obtained in a study of the effects of surface mining on fishing resources are compiled. bout 2 million acres of fish and wildlife habitat are damaged by mining. This includes 3,000 miles of streams (135,970 acres), 281 lakes (102,630 acres), 168 reservoirs (41,516 cres) and 1,687,288 acres of land; 63 percent of the damage is east of the Mississippi. roblems are discussed and recommendations are made for their solutions.

16. Stewart, R. E., Jr.
1975. New energy research in the Fish and Wildlife Service. In Fort Union Coal Field Symp. Proc., vol. I, administrative section. p. 81-86. W. F. Clark, ed. East. Mont. Coll. Bookstore, Billings.

17. Watson, A. P., R. I. Van Hook, D. R. Jackson, and others.
1976. Impact of a lead mining-smelting complex on the forest-floor litter anthropod fauna in the New Lead Belt region of southeast Missouri. M.S. thesis. Univ. Kentucky, Lexington. 178 p. [Available NTIS as ORNL/NSF/EATC30.]

tudies of biological activity within the litter horizons of a watershed contaminated by missions from a lead-ore processing complex focused on the litter-arthropod food chain as a eans of detecting perturbations in a heavy-metal contaminated ecosystem. Both point sources smelter stack emissions) and fugitive sources (ore-handling processes, yard dusts, and exposed oncentrate piles) contributed to the Pb, Zn, Cu, and Cd levels in the study area. Arthropod rophic level density, biomass, and heavy metal content were determined by analysis of specimens emoved from litter by Von Tullgren funnel extraction, taxonomically classified, and segregated nto the trophic categories. Changes in litter decomposition were reflected in the dynamics f the litter arthropod community. Food-chain dilution of Pb, An, Cu, and Cd from litter to itter consumer was occurring, as indicated by the mean concentration factors. Accumulation f Pb by litter consumers was much less than that found for the other three heavy metals. In ontrast, predatory arthropods on Crooked Creek Watershed either concentrated or equilibrated ith respect to Pb, Zn, and Cd from their prey, as indicated by mean total predator concentraion factors. A significant depression of the Ca, Mg, and K content litter occurred relative o the control within 0.8 km of the stack. Two mechanisms were postulated to explain this esult: increased leaching of cations through the litter induced by a loss of cation exchange apacity, a decrease in pH, and a decrease in microbial immobilization of macronutrients; and decreased uptake of macronutrients due to root damage produced by heavy-metal concentrations.

J. Effects on Human Health

Many of the citations in section J are related to industrial hygiene and the health of the miner. Also included are citations dealing with the impacts of certain commodity mining on the general health of the public.

518. Archer, V. E., D. Holaday, and others.
1973. Mortality of uranium miners in relation to radiation exposure, hard-rock mining, and cigarette smoking, 1950 through September, 1967. Handb. Exp. Pharmacol. 36:571-578.

519. Archer, V. E., J. D. Gillam, and L. A. James.
1975. Respiratory disease mortality among uranium miners as related to height, radiati smoking and latent period. 30 p. Paper presented at 1975 Annu. Meet., Am. Public Health Assoc. [Available NTIS as HRP-000 6691/OST.]

A prospective mortality study using a life table method was done on 3,366 white underground uranium miners, and 1,231 surface workers. Observed deaths were found to exceed those expecte from respiratory cancer, pneumoconiosis, and related diseases; and accidents related to work. Exposure-response relationships with radiation varied with cigarette smoking and with height of workers. Of four factors involved in both malignant and nonmalignant respiratory diseases (height, free silica, cigarette smoking, and alpha radiation), radiation was considered to be most important.

520. Australian Mineral Foundation Inc.
1972. Radiation controls in uranium mining. Health session. 118 p. Austr. Mineral Foundation, Inc., Adelaide. [Available NTIS as NP-19888.]

521. Clark, U.
1975. Natural radioactivity in the environment: the Florida phosphate study. In Seventh Annu. Natl. Conf. on Radiation Contr. 4 p. Food and Drug Admin., Rockvill Md.

Some topics discussed are: effects of phosphate mining on public health and the environment; concentrations of uranium and daughter products in phosphate ore; investigations of phosphate mining areas by the Florida Division of Health; development of an instrument for aerial surve of background radiation; evaluation of drinking water supplies; and use of waste products fro mining operations for construction material.

522. Comar, C. L.
1968. Radiation exposure of uranium miners. 36 p. Natl. Acad. Sci.-Natl. Res. Counc Washington, D.C. [Available NTIS as PB-180 247.]

Increasing attention has been given, within recent years, to observations that extended expos in some uranium mines is associated with an increase in lung cancer. Upon approval by the Federal Radiation Council, its staff carried out a study on the radiation hazards associated with the underground mining of uranium ore.

523. Hans, J. M., Jr., and R. L. Douglas.
1975. Radiation survey of dwellings in Cane Valley, Arizona and Utah, for use of uranium mill tailings. 43 p. Off. Radiation Prog., Las Vegas, Nev. [Available NTIS as PB-245 869/3ST.]

A radiation survey was conducted in the Cane Valley area of Monument Valley, on the Navajo Reservation, to identify dwellings in which uranium mill tailings had been used and to assess the resulting radiation exposures. Sixteen of the 37 dwellings surveyed were found to have tailings and/or uranium ore used in their construction. Tailings were used in concrete floor exterior stucco, mortar for stone footings, cement floor patchings, and inside as cement "plaster." Uranium ore was found in footings, walls, and in one fireplace. Other structures not used as dwellings, were also identified as having tailings and ore use. Gamma ray exposu ates were measured inside dwellings and structures identified as having tailings and/or ore sed in their construction. Indoor radon progeny samples were collected in occupied dwellings here practical.

24. Holaday, D. A., D. E. Rushing, R. D. Coleman, and others.
1950. Control of radon and daughters in uranium mines and calculations on biologic effects. 93 p. Public Health Serv., Bur. State Serv., Washington, D.C. [Available NTIS as PB-216 579.]

steadily mounting rate of uranium production has focused increasing attention on the health azards associated with the mining of this strategic metal. Predominant among these hazards s exposure to radon, a dense gas emanating from the ore, together with the products which esult from the radioactive decay of radon. To date, neither records of human exposure to adon daughter products nor data from animal experimentation have been available in sufficient uantity to permit a determination of a maximum permissible concentration for these elements. t has therefore been necessary to establish a working level that appears to be safe, yet not nnecessarily restrictive to industrial operations. Such a level, it is believed, has been stablished and recommended in the report.

25. Hollocher, T. C., and J. J. MacKenzie.
1975. Radiation hazards from the misuse of uranium mill tailings. In The nuclear fuel cycle--a survey of the public health, environmental and national security effects of nuclear power. p. 92-115. MIT Press, Cambridge, Mass.

he extraction of uranium from ore results in a sandlike material, called tailings, that till contains most of the original radium, and in some fluids and slimes that also contain adium. Prior to 1959 the disposal and handling of these materials caused the pollution of treams and water supplies by radium in the southwestern United States. Prior to 1966 uranium ailings were used as fill and for other construction purposes around buildings. Some 3,300 uildings have been discovered to be associated with tailings in and around Grand Junction Mesa County), Colo.; some 5,000 buildings in the whole of Colorado; and perhaps 7,000- ,000 buildings altogether in the United States. The tailings emit alpha-rays and radon gas hat expose persons indoors. In view of the situation described above and in anticipation of he milling of uranium ore that is soon to begin for the nuclear power industry, recommendations re made to alleviate the exposure.

26. Morgan, K. Z.
1978. Cancer and low level ionizing radiation. Bull. Atomic Sci. 34:30-41.

27. Saccomanno, G.
1975. Uranium miner lung cancer study. 9 p. Dep. Pathol., Saint Mary's Hospital, Grand Junction, Colo. [Available NTIS as COO-1826-32.]

he three projects supported by the Atomic Energy Commission consist of: collection of material rom uranium miners known to have cancer of the lung into a tumor registry; manual of pulmonary ytology; regression study of sputum cytological findings in uranium miners who showed marked typical squamous cell metaplasia and have quit smoking cigarettes, mining, or both. This tudy was active for the last 6 years and some interesting information is being accumulated. pproximately 60,000 sputum samples have been examined over the last 17 years in cases that howed normal cytology at the inception of study and subsequently developed carcinoma of the ung.

28. Saccomanno, G.
1976. Uranium miner lung cancer study. 8 p. Dep. Pathol., Saint Mary's Hospital, Grand Junction, Colo. [Available NTIS as COO-1826-35.]

his study on the rate of lung cancer development in uranium miners was initiated in 1957 by he U.S. Public Health Service and many facets of this project are reaching final objectives. any new studies have developed in the course of this study and will continue. The projects upported by the Energy Research and Development Administration are of utmost importance and consist of: collection of material from uranium miners known to have cancer of the lung into a tumor registry; manual on pulmonary cytology; regression study of sputum cytological findings in uranium miners who showed marked atypical squamous cell metaplasia and have quit smoking cigarettes, mining, or both; continuation of sputum collection and collection of lungs from deceased miners; and the development of instruments such as UV fiber-optic bronchoscopies for localization of carcinoma in situ of the lung. Approximately 75,000 sputum samples were examined over the last 19 years in cases that showed normal cytology at the inception of study and subsequently developed carcinoma of the lung and this has resulted in an accumulation of material that is worthy of study.

529. Swift, J., J. Hardin, and H. Calley.
1976. Potential radiological impact of airborne releases and direct gamma radiation to individuals living near inactive uranium mill tailings piles. 38 p. U.S. Environ. Protec. Agency, Washington, D.C.

530. Wagner, V., J. Andrlikova, V. Palek, and others.
1978. Levels of immunoglobulins (IGG IGA IGM) under effect of age and exposure to mining environment in uranium industry. Inst. Uranium Ind., Res. Dep., Public Health, Pribram, Czechoslovakia, Strahlentherapie 154(6):406-412.

531. Yamamoto, R., E. Yunoki, M. Yamakawa, and others.
1974. Studies on environmental contamination by uranium: 5. Uranium contents in daily diet and in human urine from several populations around a uranium mine in Okayama Prefecture. J. Radiation Res. 15(3):156-162.

K. Other Effects

Section K deals with other effects of surface mining on the environment and includes ffects on archaeology, noise, and trace elements.

32. Jennett, J. C., A. J. Callier, and J. Foil.
1976. Trace metal and trace organic emissions to the environment by lead-zinc mining and milling operations. In Trace substances in environmental health [Proc., Univ. Missouri's 10th Annu. Conf.]. p. 251-264.

33. Jennett, J. C., B. G. Wixson, I. H. Lowsley, and others.
1977. Transport and distribution of lead from mining, milling, and smelting operations in a forest ecosystem. In Lead in the environment. p. 135-178. W. R. Boggess and B. G. Wixson, eds. National Science Foundation, Washington, D.C.

34. Laguros, J. G., J. F. Harp, and J. M. Robertson.
1978. Hydrogeotechnic considerations in surface mined lands. 12 p. Paper presented at Am. Geophys. Union, San Francisco, Calif., Dec. 1978.

he paper focuses on the hydrogeotechnic elements that should be considered in the development f an effective rehabilitation program.

35. Olson, A. P.
1975. Archaeological investigation and mitigation in the Three Corners area. In Environmental Oil Shale Symposium Proc. p. 89-93. Colo. Sch. Mines Quar. 70(4). 244 p.

36. Savich, M.
1974. Production, characteristics and abatement of noise from light and medium rock drills. Can. Inst. of Mining and Metall. Bull. 67(751):66-79.

esearch was conducted to investigate the possibilities of noise abatement in light and medium ock drills. Detailed analysis of the theoretical and experimental solutions of light and edium rock drills showed that the relationships among force, thrust (penetration increase), nd noise remained unresolved. The main characteristics of two medium rock drills--Type 2 ock drill and Type 3 muffled rock drill--were investigated and analyzed. For the comparative nalysis of noise measurement, the Type 1 feed-leg drill was used. These investigations howed that rock drill noise is generated in the following manner: at frequencies below 125 z, by the impact between the piston and drill steel; at frequencies between 125 and 2000 Hz, y the exhaustion of air from the exhaust ports; and at frequencies above 2000 Hz, by the mpact between the piston and drill steel, and between the drill steel and rock. Analysis howed that the system for noise abatement in rock drills can be further improved. In this esearch project, a proposition to achieve this end is given. To perform these measurements, he author gave his own variant of an anechoic chamber, constructed exclusively for the measure-ent of the noise of light and medium drills under different power thrusts.

37. Schreibeis, W. J., and H. H. Schrenk.
1961. Evaluation of dust and noise conditions at typical sand and gravel plants. 23 p. Natl. Sand and Gravel Assoc., Washington, D.C.

38. Weaver, T., and D. Klarich.
1973. Ecological effects of silver iodide in terrestrial ecosystems: a preliminary study. Mont. Agric. Exp. Stn., Bozeman, Res. Rep. 42, 19 p.

L. Reclamation Efforts and Revegetation

Citations included in section L are those that deal primarily with reclamation and reveget-tion effects, techniques and equipment used for reclamation, and resource and guideline books for reclamation.

539. Anderson, M. A.
1976. Microbial bioassay techniques for assessing acid mine spoil amendments for revegetation. M.S. thesis. Utah State Univ., Logan. 117 p.

540. Angster, G. L., and others.
1970. Reclamation. 43 p. N.C. Univ., Raleigh. [Available from Nello L. Teer Company, Durham, N.C.]

541. Bamberg, S. A.
1975. Approaches to large scale land reclamation in oil shale development. In Environmental Oil Shale Symposium Proc. p. 95-105. J. H. Gary, ed. Colo. Sch. Mines Quar. 70(4).

542. Bengson, S. A.
1976. How drip irrigation revegetates mine wastes in an arid environment. Mining Eng. 28:45-46.

Bengson discusses advantages and disadvantages of a drip irrigation for revegetation in arid environments. Advantages include: reduces hazard of runoff and erosion and promotes vigorous plant responses. Disadvantages include: cost, spatial arrangement of plants (linear), and inefficient for establishing solid plant cover. Drip irrigation is a helpful tool for some revegetative problems but not for all situations.

543. Bjugstad, A. F.
1977. Reestablishment of woody plants on mine spoils and management of mine water impoundments: an overview of Forest Service research on the northern High Plains. In The reclamation of disturbed lands. p. 3-12. Robert A. Wright, ed. Univ. N.Mex. Press, Albuquerque.

544. Bourdo, E., and G. Willis.
1975. Borrow pit reforestation. Mich. Tech. Univ. Res. Note 17, 8 p. L'anse, Mich.

Along the highways of the Upper Peninsula, numerous acres have been stripped for rill, gravel, or crusher rock. Although most pits are of limited size (less than 40 acres), the sum total of the area concerned amounts to thousands of acres. Some pits have not become reforested after more than 50 years. To test the feasibility of reforesting such an area, a Ford Forestr Center "borrow pit" was planted with a variety of tree species, native and introduced, to determine which were best adapted for growth on coarse gravelly materials from which topsoil had been stripped.

545. Brown, D.
1977. Equipment for reclaiming strip mined lands. USDA For. Serv., Equip. Develop. Cent. Handb. 7728-2503, 58 p. Fort Missoula, Mont.

546. Brown, L. F.
1976. Reclamation at Climax, Urad and Henderson Mines. Mining Congr. J. 62(4):42-43.

The three Amax Inc. molybdenum mines in Colorado have had active reclamation programs for years. The company began tailings revegetation research in 1965 at the Climax Mine near Leadville. The research is extremely important because all three mines are at timberline along the Continental Divide. Mine elevations range from 10,300 to 11,300 ft above sea level. These altitudes result in severe winters and very short growing seasons. The average annual temperature is slightly below freezing. The growing season, as depicted by consecutive frost-free days, can be expected to last only 6 to 8 weeks. Seed of grass species native to these levations is not commercially available. Therefore, much of the company's research has been irected toward determining which commercially available seed species are adaptable to these xtreme conditions. The oldest high-altitude-species adaptation plots in Colorado are at the limax Mine. Reclamation at each mine must be approached differently. Each mine has a unique istory and a different status with respect to future production and environmental planning.

47. Brown, R. W., and R. S. Johnston.
1976. Revegetation of alpine disturbances. Range Guide 2(2):2-3.

48. Brown, R. W., and R. S. Johnston.
1976. Revegetation of an alpine mine disturbance: Beartooth Plateau, Montana. USDA For. Serv. Res. Note INT-207, 8 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

he first-year results of revegetation research on an alpine mine disturbance on the Beartooth lateau in Montana are discussed. Plant densities were highest on plots treated with topsoil nd fertilizer. Native seed mixtures produced higher plant densities than did introduced seed ixtures on both topsoil and raw spoil plots. Transplanting of native plants was also studied s an alternative revegetation technique. All transplants survived after 1 year, suggesting hat this method offers an excellent opportunity for plant establishment on alpine disturbances.

49. Brown, R. W., and R. S. Johnston.
1978. Rehabilitation of a high elevation mine disturbance. In Proc. Workshop on Revegetation of High Altitude Disturbed Lands. p. 116-130. Colo. State Univ. Infor. Series No. 28.

ince Harrington's (1946) early efforts on Trail Ridge in Colorado, very little research has een devoted to the development of high elevation revegetation methods. This research was nitiated on the Beartooth Plateau in 1972 to develop rehabilitation methods. Studies included everal different aspects of rehabilitation such as consideration of (1) plant succession, (2) pecies adaptability, (3) characterization of microenvironmental factors, including soils and ydrologic phenomena (see Johnston and others 1975), (4) revegetation trials by seeding and ransplanting (see Brown and Johnston 1976; Brown and others 1976), and (5) laboratory bioassays. uring the 1976 growing season the combined results of these various studies were applied to a arger scale rehabilitation demonstration effort on the McLaren Mine in the Beartooth Mountains f Montana. The objective of this effort was to develop a rehabilitation plan which would ead to the establishment of a stable plant cover on relatively sterile acid-producing spoils n a high elevation environment. Also, it was intended to demonstrate that the results from mall revegetation plots and other studies could be applied to large scale rehabilitation fforts.

50. Brown, R. W., R. S. Johnston, and D. A. Johnson.
1978. Rehabilitation of alpine tundra disturbances. J. Soil Water Conserv. 33:154-160.

lpine tundra is defined and the extent and nature of disturbances reviewed. Twelve percent f alpine tundra requires rehabilitation. Characteristics of the alpine tundra are discussed, ncluding climate, geology, soils, and vegetation. The paper includes a section on the adaptations required by plants (growth form, drought resistance). Plant breeding potential is eviewed. A section on rehabilitation recommendations is included. Contouring, shaping, plant pecies selection, time of seeding, fertilizer, and other soil treatment and postplanting anagement are covered.

51. Brown, R. W., and R. S. Johnston.
1978. Rehabilitation of disturbed alpine rangelands. In Proc., First Int. Rangeland Congr. p. 704-706. Soc. Range Manage., Denver, Colo.

52. Brown, R. W., and R. S. Johnston.
1979. Revegetation of disturbed alpine rangelands. In Special management needs of alpine ecosystems. p. 76-94. D. A. Johnson, ed. Soc. Range Manage., Range Sci. Series No. 5.

553. Brown, R. W., R. S. Johnston, and K. Van Cleve.
1978. Rehabilitation problems in alpine and arctic regions. In Proc. Symp., Reclamati
of Drastically Disturbed Lands. p. 23-44. Am. Soc. Agron., Madison, Wis.

This paper provides a comprehensive summary and discussion of the nature and extent of the problems in rehabilitation of tundra. Type and extent of disturbance are discussed. Environmental factors affecting rehabilitation including climatic facts, geology, and soils are covered. There is a comprehensive section on plant species adaptability and selection. Recommended techniques for rehabilitation are given.

554. Brown, R. W., R. S. Johnston, B. Z. Richardson, and others.
1976. Rehabilitation of alpine disturbances: Beartooth Plateau, Montana. In Proc., Workshop on Revegetation of High Altitude Disturbed Lands. p. 58-73. Colo. State Univ., Fort Collins, Infor. Series No. 28.

The current research program in the rehabilitation of alpine disturbances was begun in 1972, and has since been incorporated into the SEAM (Surface Environment and Mining) Program of the USDA Forest Service. The research program has grown to include the following activities: (1) revegetation research on disturbed sites including seeding, species trials, and transplanting; (2) plant succession on disturbed sites; (3) physiology of plants on disturbed sites; (4) water quality research, including surface water quality, soil water chemistry, and impact of roads on storm regimen and water quality; (5) microenvironmental characteristics of alpine disturbance; and (6) snow accumulation and melt related to micro- and macro-surface configurations of mine surfaces.

555. Burdick, M. D.
1974. SCS and the oil shale program. Soil Conserv. 40(11):4-6,18.

556. Butterfield, R. I.
1977. The revegetation potential of the Leviathin Mine spoils. M.S. thesis. Univ. Nevada, Reno. 72 p.

557. Conwell, C. N.
1975. Reclaiming mined lands in Alaska. Am. Inst. of Mining, Metallurgical, and Petroleum Eng., Soc. of Mining Eng. preprint 75-AO-304, 10 p.

558. Cook, C. W.
1974. Surface rehabilitation of land disturbances resulting from oil shale development
Colo. State Univ., Environ. Resour. Cent., Fort Collins, Infor. Series 11, 56 p.

559. Cook, C. W.
1976. Surface-mine rehabilitation in the American West. Environ. Conserv. 3(3):179-183.

560. Cundell, A. M.
1977. The role of microorganisms in the revegetation of strip-mined lands in the western United States. J. Range Manage. 30(4):299-305.

561. Dai, T. S., and A. Langevin.
1978. Revegetation activities - 1977. 54 p. Syncrude Canada Ltd.

The 1977 revegetation activity is a continuation of the reclamation program that commenced on disturbed lands in 1976. The majority of the area treated was disturbed as a result of water diversion projects and construction activity. Activities in 1977 included site preparation, seeding and fertilizing, and postseeding treatment in the form of reseeding in erosion areas and application of fertilizer for vegetation maintenance. A total of 175 ha (429 acres) were treated as primary revegetation sites and 147 ha (364 acres) as secondary treatment. Selectio of seed and fertilizer for the 1977 program was based on the previous year's plant performance and soils evaluation. Reforestation trials were initiated in select locations to provide preliminary data on woody plant establishment, planting techniques, and survival rates.

62. Day, A. D., and K. L. Ludeke.
1973. Stabilizing copper mine tailing disposal berms with giant bermudagrass. J. Environ. Qual. 2(2):314-315.

63. Day, A. D., and others.
1976. Copper mine wastes: good potential as medium for growing livestock forage. Eng. and Mining J. 177(2):90-91.

64. Day, A. D., K. L. Ludeke, and T. C. Tucker.
1977. Influence of soil materials in copper mine wastes on the growth and quality of barley grain. J. Environ. Qual. 6(2):179-181.

xperiments were conducted in Arizona to study the effects of four soil materials in copper
ine wastes (desert, overburden, tailing-overburden, and tailing) on the growth, grain yield,
nd grain quality of barley. Barley was effective in the revegetation and stabilization of
he four soil materials in Cu mine wastes. It also provided needed organic material to be
ncorporated into the surface 15 cm, which created a more suitable soil medium for the establish-
ent of perennial grass species. When grown in desert soil and overburden, barley produced
aller plants, more vegetative plants, higher grain yields, and grain of higher quality than
hen it was produced in tailing-overburden and tailing soil materials. Barley can be used
ffectively to produce satisfactory grain yields and grain of suitable quality for livestock
nd wildlife and feed in the rehabilitation of desert soil, overburden, tailing-overburden,
nd tailing soil materials in copper mine wastes.

65. Dean, K. C., R. Havens, and K. T. Harper.
1969. Chemical and vegetative stabilization of a Nevada copper porphyry mill tailing. 18 p. U.S. Bur. Mines, Washington, D.C.

he Bureau of Mines stabilized 10 acres of windblown copper mill tailings at McGill, Nev., by
combination chemical-vegetative procedure. Legumes, winter wheat, wheatgrasses, and wild
ye were seeded, and the area was subsequently sprayed with a resinous adhesive chemical to
tabilize the sands until the vegetation could grow. During the year since treatment, the
rea has been well stabilized against wind erosion. The established vegetation appears to be
apable of self-perpetuation and renewal without irrigation. The cost of stabilizing the area
as $135.50 per acre.

66. Deichmann, J. W., and L. D. Potter.
1977. Environmental factors affecting natural succession on coal mine spoils. Final Rep., contract 16-552-CA, 58 p. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins.

67. Donovan, R. P., R. M. Felder, and H. H. Rogers.
1976. Vegetative stabilization of mineral waste heaps. 318 p. Research Triangle Inst., Research Triangle Park, N.C. [Available NTIS as PB-252 176/3ST.]

he report reviews the establishment of vegetative cover as a candidate method for reclaiming
ineral ore waste heaps. It begins by describing the location and properties of spoils and
ailings from mining and ore beneficiation, and briefly reviews present methods for controlling
ust emissions from them. Most of the report develops fundamentals for establishing vegetative
over, and gives a detailed review of case histories of both successful and unsuccessful
evegetation. The report also contains a catalog of individual plant species. This mass of
nformation can be used to provide general guidelines for establishing vegetative cover.

68. Eddleman, L., and P. Doescher.
1978. Selection of native plants for spoils revegetation based on regeneration characteristics and successional status. In Land reclamation program, annual rep. p. 132-134. Argonne Natl. Lab., Argonne, Ill.

569. Eddleman, L., and P. L. Meinhardt.
1977. Indigenous plants of southern Montana. I. Viability and suitability for reclamation in the Fort Union Basin. Mont. For. and Conserv. Exp. Stn., Univ. Mont., Missoula, Spec. Publ. 4, 122 p.

570. Eddleman, L., and P. L. Meinhardt.
1978. Survey of viability of indigenous grasses, forbs, and shrubs. U.S. Dep. Energy, Annu. Prog. Rep. 183, 48 p.

571. Eddleman, L., P. L. Meinhardt, and P. S. Doescher.
1977. Selection of native plants for spoils revegetation based on regeneration characteristics and succession of status. 97 p. Completion Rep., Argonne Natl. Lab., Argonne, Ill.

572. Engineering and Mining Journal.
1970. Cyanamid shoots for instant reclamation of mined lands. Eng. and Mining J. 171(1):90-92.

A novel land reclamation technique practiced by American Cyanamid Co., at its open pit operati in Florida, consists of disposing flotation and slime tailings in mined out areas in a way that produces quick compaction and better water recovery.

573. Everett, H. W.
1974. Progress in stabilizing manganese mine spoil. Soil Conserv. 40(1):19-20.

574. Farmer, E. E., and W. G. Blue.
1978. Reclamation of lands mined for phosphate. In Reclamation of Drastically Disturb Lands. p. 585-608. F. W. Schaller and P. Sutton, eds. Agron. Soc. Am., Crop Sci. Soc. Am., Soil Sci. Soc. Am., Madison, Wis.

This paper reviews current technology and know-how for reclamation of phosphate-mined lands. Problems which are not being approached nor worked on are identified. Preventable revegetatio failures are identified and corrective measures given. Recommended treatments of fertilizer, topsoil, irrigation, and mulch are covered. Seeding mixtures and rates are also covered. Climatic variations and plant resources are also reviewed.

575. Farmer, E. E., R. W. Brown, B. Z. Richardson, and others.
1974. Revegetation research on the Decker coal mine in southeastern Montana. USDA For. Serv. Res. Pap. INT-162, 12 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

First-year results of revegetation research at the Decker coal mine in southeastern Montana are described. Three types of main plots were located on overburden material: (1) a control plot, (2) an irrigated plot, and (3) a plot dressed with topsoil materials. Each main plot consists of 48 subplots for a total of 144 subplots. Treatments included different grass mixtures, fertilizer, and mulch on irrigated and unirrigated plots. On the basis of dry-weight grass production, several treatments produced acceptable first-year grass stands. The top-dressing of mine overburden appears to be a highly desirable revegetation practice. Generally, wheatgrasses (*Agropyron* spp.) have dominated the dry-weight production.

576. Farmer, E. E., B. Z. Richardson, and R. W. Brown.
1976. Revegetation of acid mining wastes in central Idaho. USDA For. Serv. Res. Pap. INT-178, 17 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

The results of 2 years of revegetation research on acid mining wastes in central Idaho are described. Three types of main plots were used, each containing 12 treatments. Treatments are evaluated in terms of both vegetative production and ground cover. Vegetative species are evaluated in terms of their density and persistence under different treatment conditions. Coupled with a fertilization program, top-dressing of mining wastes with selected overburden materials appears to be a highly desirable revegetation practice.

77. Fitter, A. H., and A. D. Bradshaw.
1974. Responses of *Lolium perenne* and *Agrostis tenius* to phosphate and other nutritional factors in the reclamation of colliery shale. J. Appl. Ecol. 11(2):597-608.

78. Grigg, N. S.
1976. Precipitation management for reclamation of overgrazed areas in arid and semiarid regions. 13 p. Colo. Environ. Resour. Cent., Fort Collins. [Available NTIS as PB-251-166.]

n investigation was made of the feasibility of utilizing precipitation management as a method or the vegetative restoration of strip mine spoils in arid and semiarid areas, and for the conomic and environmental improvement of reclaimed mine spoils. The procedure is believed to e capable of producing vegetative systems of higher economic and wildlife habitat value than xists naturally on these same lands or might be produced by other nonirrigated methods. It ould appear that the cost of the necessary Research and Development program would be minimal, articularly when compared with the potential economic, environmental, and social benefits hat would accrue.

79. Harbert, H. P., III, and W. A. Berg.
1978. Vegetative stabilization of spent oil shales: vegetation moisture salinity and runoff, 1973-76. 183 p. Colo. State Univ., Fort Collins. [Available NTIS as PB-280 308/8ST.]

isposal of massive amounts of spent shale will be required if an oil shale industry using urface retorting is developed. Field studies were initiated in 1973 on two types of spent il shale--coarse-textured (USBM) and fine-textured (TOSCO). The objectives of these studies ere to investigate surface stability of and salt movement in spent shales and spent shales overed with soil after vegetation has been established by intensive treatment and then left nder natural precipitation conditions. The plots were established at low-elevation (1 700 m) nd high-elevation (2 200 m) study sites in northwestern Colorado. A good cover of native pecies was established on all plots by leaching, N and P fertilization, seeding, mulching, nd irrigation. High levels of Mo were found in plants grown in the spent shales compared to lants grown in soil. Resalinization occurred following leaching of the TOSCO spent shale. he greatest runoff was from the TOSCO spent shale. Runoff was moderately to highly saline.

80. Harris, M. M., and M. F. Jurgensen.
1977. Development of *Salix* and *Populus* mycorrhizae in metallic mine tailings. Plant and Soil 47(2):509-517.

81. Hogan, G. D., G. M. Courtin, and W. E. Rauser.
1977. Copper tolerance in clones of *Agrostis gigantea* from a mine waste site. Can. J. Bot. 55(8):1043-1050.

82. Hortenstine, C. C., and D. F. Rothwell.
1972. Use of municipal compost in reclamation of phosphate-mining sand tailings. J. Environ. Qual. 1(4):415-417.

83. Howard, G. S., G. E. Schuman, and F. Rauzi.
1977. Growth of selected plants on Wyoming surface-mined soils and flyash. J. Range Manage. 30(4):306-310.

84. Howard, P. L.
1978. Plant succession studies on sub-alpine acid mine spoils in the Beartooth Mountains. M.S. thesis. Utah State Univ., Logan. 93 p.

85. Johnson, M. S.
1976. Plant growth on fluorspar mine tailings. J. Soil Water Conserv. 31(1):17-20.

586. Johnson, M. G., A. D. Bradshaw, and J. F. Handley.
1976. Revegetation of metalliferous fluorspar mine tailings. Inst. Mining and Metallur
Trans. 85:A32-A37.

Waste materials produced during the processing of raw mineral ore containing fluorspar are deposited in large tailings dams whose impact on the surrounding countryside may be reduced considerably by a vegetation cover on the tailings. The experimental trials carried out to determine the effects on plant growth of heavy metals in fluorspar tailings indicate that the major limitations to plant growth were the very low levels of nitrogen and phosphorus. It appears that a seed mixture with a high legume content, supplied with adequate phosphorus, is the key to the development of a low-maintenance permanent-cover vegetation on the tailings dam.

587. Johnson, M. S., T. McNeilly, and P. D. Putwain.
1977. Revegetation of metalliferous mine spoil contaminated by lead and zinc. Environ. Pollution 12(4):261-277.

588. Johnston, R. S., R. W. Brown, and J. Cravens.
1975. Acid mine rehabilitation problems at high elevations. Symp. Proc., Watershed Manage., Am. Soc. Civil Eng. p. 66-79. Utah State Univ., Logan.

A multiagency study of problems associated with alpine and subalpine mining activity has been initiated at several sites near Cooke City, Mont. With cooperation from mine owners and lessees, a demonstration project of mine disturbance rehabilitation techniques has been funded by the Environmental Protection Agency and is administered by the State of Montana, Department of Natural Resources and Conservation. The purpose of the project is to demonstrate the adaptability of existing technology to solve mining problems in the alpine and subalpine zones. These rehabilitation problems include: the reduction or elimination of acid mine drainage; slope stabilization to reduce erosion and sedimentation; revegetation of disturbed areas; and elimination of the visual impact of mining in a heavily used recreation area. Large amounts of inventory data are being assembled as part of the problem evaluation.

589. Jonas, R. S., and W. C. Sharp.
1970. Conservation action: greenbacks bring green back to gravel mines. Soil Conserv. 35(9):208.

590. Kaiser Sand and Gravel Company.
1973. Kaiser random land reclamation project. 16 p. [Authorized reprint by Natl. Sand and Gravel Assoc.]

591. Keller, H., and J. C. Leroy.
1975. The systematic reclamation of gold mine tailings. Can. Mining J. 96:45-46.

Erocon's work is the reclamation of mine wastelands. It has considerable experience particular in the reclamation of gold mine tailings in the Canadian Shield since the latter part of the sixties when most gold mines were closing down. A well developed continuous vegetation cover has a remarkable regulatory effect on natural precipitation. The latter can be highly destruct on unprotected tailings and slime ponds. The established vegetation will be able to cope with heavy precipitation, practically eliminating the immediate surface runoff and its resulting deep erosional features, overload sedimentation of streams, landslides, mudflows, contaminatio of water with freed toxic fluids, etc. The developing vegetation cover will cause the tailings to become firm, will create a soil and provide well drained flatlands, which can be a definite asset in some rugged areas of the Canadian Shield. Nurseries, sod farms, cattle farms, recreation areas, and golf courses are considered as some of the ultimate uses of these so-called "wastelands."

592. Kelley, N. E.
1978. Vegetational stabilization of uranium spoil areas, Grants, New Mexico. Ph.D. diss. Univ. N.Mex., Albuquerque. 89 p.

93. Kenny, S. T., ed.
1978. Proceedings: High Altitude Revegetation Workshop No. 3. Colo. Water Resour. Res. Inst., Infor. Series No. 28, Colo. State Univ., Fort Collins.

opics included are ecology of alpine plants; problems in the identification of threatened and ndangered species; political and economical implications of reclamation; plant materials evelopment construction and design techniques; etc.

94. Kneib, W. A.
1978. Manure additions improve revegetation success on amended mine spoils. M.S. thesis. Utah State Univ., Logan. 138 p.

95. Kremmel, D. G.
1976. Chemical additives as an aid in reclamation programmes. In Proc., Seminar on Landscaping and Land Use Planning as Related to Mining Operations [Mar.-Apr. 1976]. p. 251-257. Australas. Inst. Mining and Metallurgy, Victoria, Austr.

he prevention of erosion from slopes, banks, and batters following open cut mining is an area n which chemicals are being successfully used to achieve the desired results. Most of these roducts can be classified under one of the following three broad categories: neutral fibrous gents, such as straw, hay, wood shavings, burlap, cloth, tires, and wood mats; synthetic and olymeric materials, such as latex and epoxy compounds, crosslinked polymers, linear polymers rosslinked in place, drying oils, and bitumen; rocks and silicates, such as gravel, riprap, nd sodium silicates.

96. Lagerwerff, J. V., and W. D. Kemper.
1975. Reclamation of soils contaminated with radioactive strontium. Soil Sci. Soc. Am. Proc. 39(6):1077-1080.

vesboro loamy sand, Sassafras sandy loam, and Fort Collins silt loam were treated with a ixed Ca-Sr solution to give about 95 percent saturation with Ca and 5 percent saturation with r. Samples of these soils were placed in acrylic cylinders and leached with 0.06N $CaCl_2$ to emove Sr. The leachings were mechanically controlled at various rates for different periods f time. Extracting the leached soil samples with 1N HCl yielded residual Sr equal to 0.43, .47, and 0 percent of the Sr exchange capacity of the Evesboro, Sassafras, and Fort Collins oils, respectively. There was general agreement between Sr concentrations measured at various epths and those calculated on the basis of the Lapidus-Amundson equation, especially so with eavier soils. The Evesboro and Fort Collins soils were also tagged with carrier-free Sr85 nd, mounted in columns, leached with 0.06N solutions of either $CaCl_2$ or $SrCl_2$. The removal f Sr85 was more complete from the Evesboro than from the Fort Collins soil, and from the enter than from the edge of the columns. Short-term leaching capability of $SrCl_2$ exceeded hat of $CaCl_2$ where Sr85 was present in amounts small enough to be absorbed mostly on specific oil absorption sites. Where larger amounts of Sr85 had been absorbed, Ca was as equally ffective as Sr in replacing the contaminant.

97. Land Rehabilitation Advisory Board, Department of Soil Conservation.
1973. Recommendations for establishment of vegetation on surface mined areas, Des Moines, Iowa. 13 p.

his paper is a handbook on recommended techniques for establishment of vegetation on surface ined areas of Iowa. Subjects covered include: site preparation, soil testing, lime requirements, ertilization, seedbed preparation, time of seeding, seeding mixtures and rates, establishment f trees and shrubs, and weed control.

98. Langevin, A., and P. D. Lulman.
1977. Revegetation activities - 1976. 79 p. Syncrude Canada Ltd.

During the spring of 1976, the first year of revegetation on Syncrude Lease #17, approximately 138 ha (340 acres) of land were treated for revegetation. The land was handed over by project construction in a shaped and graded condition suitable for immediate seeding. The prime objective of the program has been to create a viable vegetation cover, minimizing erosion of exposed surface soil. The 1976 revegetation program has been carried out cooperatively by Operations-Conservation and Environmental Affairs. Following application, field plots were set up on all major areas treated in 1976. Results from these plots have demonstrated a need for a less diverse seed mixture applied at lower rates per acre. Nitrogen is the major limiti nutrient in soil and appropriate fertilizers are recommended to correct this deficiency. A two-phase approach to hydroseeding and mulching is recommended for most effective use of mulch. "Rough" seedbeds, harrowed or tilled, are more conducive to rapid germination and strong establishment of vegetation than smoothly graded surfaces. Clay is an essential ingred ent for maintenance of seedbed fertility.

599. Lawrence, E. A.
1974. Summary of vegetation program on lead-zinc tailings. Am. Inst. Mining, Metallur cal, and Petroleum Eng., Soc. Mining Eng., Trans. 256(4):306-307.

600. Lewis, J. W.
1976. Regeneration of coastal ecosystems after mineral sand mining. Austr. Mining 68(7):27-29.

601. Lindstrom, G. A.
1960. Forestation of strip-mined land in the Central States. USDA For. Serv., Agric. Handb. 166, 74 p. Washington, D.C.

602. Ludeke, K. L.
1973. Stabilizing copper mine tailing disposal berms with giant bermudagrass. J. Environ. Qual. 2(2):314-315.

603. Ludeke, K. L.
1973. Vegetative stabilization of tailings disposal berms. Mining Congr. J. 59:32-39.

604. Ludeke, K. L.
1976. Evaluation and selection of spring barley (*Hordeum vulgare* L.) for the revegetat and stabilization of copper mine tailing disposal berms. Ph.D. diss. Univ. Ariz. 68 p. [Diss. Abstr. Int. 37/06B:2612.]

605. McMillan, H., and R. Carlson.
1975. Using wastewater solids to reclaim strip-mined land. Trans. Soc. Mining Eng. AIME 258(4):273-278.

Land application as a method of using the solids produced in the wastewater treatment process and demonstrations on farmland, reclamation of acid strip-mine spoils, fertilizing a landfill, and reclamation of an alkaline sand waste pit are discussed and presented in tabular and graphical form.

606. May, J. T.
1975. Renewal of china clay strip mining spoil in southeastern United States. In The ecology of resource degradation and renewal. [Brit. Ecol. Soc., 15th Symp., Univ. of Leeds, Yorkshire, July 10-12, 1973, Proc.] p. 351-361. John Wiley and Sons, New York. 480 p.

607. May, J. T.
1977. Highlights of a decade of research and reclamation of kaolin clay strip mining spoil, 1966-1976. Georgia For. Res. Counc. Rep. 37, 36 p.

This paper reviews the research on reclamation and revegetation of kaolin clay spoils, includi a section on industry innovations. Spoil properties and soil genesis, hydroseeding, aerial seeding, and tree planting studies are covered. The summary includes recommended fertilizatio planting techniques, ground cover and tree establishment, and useful plant species.

08. May, J. T., C. L. Parks, and H. F. Perkins.
1973. Establishment of grasses and tree vegetation on spoils from kaolin clay strip-mining. In Ecology and reclamation of devastated land, vol. 2. p. 137-147. Gordon & Breach, New York.

09. May, M.
1975. Reclamation of uranium-mined areas in the United States. In The ecology of resource degradation and renewal. [Brit. Ecol. Soc., 15th Symp., Univ. of Leeds, Yorkshire, July 10-12, 1973, Proc.] p. 223-230. John Wiley and Sons, New York. 480 p.

10. Meecham, J. R., and L. C. Bell.
1977. Revegetation of alumina refinery wastes: (2) glasshouse experiments. Austr. J. Exp. Agric. 17(87):689-696.

11. Michelutti, R.
1974. How to establish vegetation on high iron-sulphur mine tailings. Can. Mining J. 95(10):54-58.

12. Mine and Quarry.
1978. Reclamation landscaping with drip irrigation. Mine and Quarry 7(4):38,40,43,45.

13. Mitchell, W. W.
1972. Adaptation of species and varieties of grasses for potential use in Alaska. In Proc., Symposium on Impact of Soil Resource Development on Northern Plant Communities [Aug. 1972, Univ. Alaska.] p. 2-6. Institute of Arctic Biology, Univ. Alaska, Fairbanks.

verview is presented of revegetation research in diverse areas of Alaska. Many grasses have roved successful in tests on mesic boreal sites of southern to central interior Alaska. Dry ites are limiting because of moisture conditions but less restrictive than more moist, peaty ites. The latter generally are acidic. Fewer grasses are successful on these sites. Tundra egions with their cooler, shorter growing seasons, are the most limiting. Alpine tundra is ore favorable for growth than arctic tundra. Certain fescues, bluegrasses, meadow foxtail nd timothy have demonstrated wide adaptability in Alaska. Alaskan soils require applications f N, P, and K for satisfactory stand establishment. Rates and ratios become more critical on eaty soils where disease problems may also affect winter survival. Native taxa offer good otential for revegetation material that would be more durable and require less maintenance han introduced taxa. Limited material is available now, but work is progressing at the gricultural institute to provide other, widely adapted materials.

14. Mitchell, W. W.
1973. Alaskan climatic and ecological patterns as related to revegetation possibilities. In 1973 Alaska Revegetation Workshop Notes. p. 51-56. Univ. Alaska, Fairbanks.

road patterns of vegetation and climate are discussed in relation to revegetation possibilities. bservations and experiences of the author on vegetational responses to climatic conditions of arsh Alaska sites from coastal rain forests to arctic and maritime tundra are given.

15. Mitchell, W. W.
1973. Using plant resources for conservation. Agroborealis (July 1973):24-25.

itchell's research on revegetation of a maritime tundra in Alaska has shown that native lants (such as Bering hairgrass) offer real potential for conservation in the North.

16. Mitchell, W. W.
1976. Revegetation research on Amchitka Island, a maritime tundra location in Alaska. U.S. Energy Res. and Develop. Admin., Nev. Oper. Off., NVO-172, 59 p.

Revegetation studies commenced by the Alaskan Agricultural Experiment Station in 1970 on Amchitka Island culminated in 1973 with the seeding of disturbed areas associated with the nuclear testing program. Cool temperatures coupled with strong winds and a high incidence of fog and cloud cover impose a tundra aspect on Amchitka. Twenty-two perennial grasses, two clovers, and four annual grasses were tested on different soil types at low to medium-high (480 ft) elevation sites. At higher elevations severe winds and frost action maintain a barren-ground aspect. Relatively humid, acidic sites were the least favorable, a test site gravel pad the most favorable. The revegetation seeding mix included Boreal red fescue, Highlight chewing fescue, Bering hairgrass, and annual ryegrass. Fertilization was necessary to establish plants on most sites.

617. Mitchell, W. W.
    1977. Arctic revegetation research. In Northeast by east: review of Alaskan arctic gas research, vol. 2, no. 3. 5 p. Alaskan Arctic Gas Study Co., Anchorage, Alaska

Both native Alaskan grasses and grasses from the boreal to temperate region were tested at revegetation trials established on the arctic gas test pipe facility at Prudhoe Bay. Sevente species of perennial grasses were tested. Selections of arctic grass, fluejoint reed grass, and a bluegrass are now being developed for commercial production.

618. Mitchell, W. W.
    1977. Grasses for revegetation in the Arctic. In Proc., Symp., Surface Protection through Prevention of Damage (Surface Management). p. 141-147. The Arctic Slope BLM State Office, Alaska.

The topic is limited to grasses applicable for use on the Arctic Slope. Prior work on native plants at the Palmer Research Station gave impetus to the particular needs for research in th Arctic. Trials began there in 1969, and some plots still being monitored are now 6 years old Materials of Alaskan origin or development in Alaska have been the most successful. Those tested from other northern regions have been found waning. The research has led to the devel ment of three new grass varieties from native plant sources.

619. Mitchell, W. W.
    1978. Development of plant materials for revegetation in Alaska. In Proc., High Altitude Revegetation Workshop No. 3 [Mar. 1978, Fort Collins, Colo.]. p. 101-115. Colo. State Univ., Fort Collins.

This paper reviews the factors (mostly climatic) which limit revegetation success in Alaska. A list of successful plant material is given. A number of native Alaska species are presentl being developed for commercial production. Native species demonstrate a high degree of variability; thus selection efforts are necessary to identify populations that possess appropriate adaptations.

620. Monsen, S. B., and D. R. Christensen.
    1975. Woody plants for rehabilitating rangelands in the Intermountain Region. In Wildland Shrubs Symposium and Workshop Proceedings [Provo, Utah]. p. 72-119. H. C Stutz, ed. Brigham Young Univ., Provo, Utah.

Considerable variability among separate collections, ecotypes, and subspecies has been observ for most shrubs, and these differences have been used to promote the development of superior traits. The forage qualities of various shrubs have been markedly improved through the select and propagation of palatable and productive collections. Plants that occur over a wide geogra cal range provide an extensive base of genetic material for breeding and selection. However, endemic collections have also demonstrated adaptability to a wide range of planting sites. Most shrubs that are useful as forage plants have proved to be well adapted to restoring othe wildland sites, particularly disturbed roadways, mine spoils, and recreation facilities.

621. Moore, T. R., and R. C. Zimmermann.
    1977. Establishment of vegetation on serpentine asbestos mine wastes, southern Quebec, Canada. J. Appl. Ecol. 14(2):589.

22. Moseley, J. R., and L. D. Potter.
1978. Ecological parameters of fourwing saltbush in relation to mine spoil reclamation. Final rep., contract 16-551-CA, 50 p. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

23. Moudgil, B. M.
1976. Mined land reclamation by the Florida phosphate industry. Trans. Soc. Mining Eng. AIME 260(2):187-191.

uring hydraulic processing of phosphate matrix enormous amounts of phosphate slimes are roduced. Significant portions of mined land are utilized to sort the slimes. Some dewatering f the slimes is essential before any reclamation of the storage ponds can be undertaken. ewatering and reclamation of slime storage ponds pose many problems which are not encountered n reclamation of other mined areas.

24. Mulamoottil, G., and R. Farvolden.
1975. Planning for the rehabilitation of gravel pits. Water Resour. Bull. 11(3):599-604.

25. Murray, D., and D. Moffett.
1977. Vegetating the uranium mine tailings at Elliot Lake, Ontario. J. Soil and Water Conserv. 32(4):171-174.

26. Mustard, E. W.
1977. From mess to marsh land reclamation, gravel mine to wildlife sanctuary, Colorado. Soil Conserv. 42(8):8-9.

27. Newey, C. O., and J. W. Lewis.
1976. Landforms and revegetation after mineral sand mining. In Proc., Seminar on Landscaping and Land Use Planning as Related to Mining Operations [Mar.-Apr. 1976]. p. 205-217. Austr. Inst. Mining and Metallurgy, Adelaide Br. (Symp. Ser. No. 13), Barkville, Victoria.

ne mineral sand ore bodies of the east coast of Australia occupy approximately 3 percent of ne dune-heath-wetland coastal environment. They are associated with coastal plant communities anging from Holocene high dunes carrying mature eucalypt forests to low-lying heaths on leistocene deposits. Commonly, 0.25 to 1.5 percent of the sand volume mined is removed from ne site. Therefore, the volume change is insignificant. The equipment and techniques in use re flexible and the land can be returned in a manner suited to its subsequent use for grazing, ubdivision, or recreation. Landforms similar to the pre-existing are created in two case tudies given. Sophisticated revegetation techniques are practiced and are discussed in two ase studies. Premining vegetation surveys and postmining monitoring are used to guide the anagement of the ecosystem.

28. Nielson, R. F., and H. B. Peterson.
1972. Treatment of mine tailings to promote vegetative stabilization. Utah State Univ., Logan, Agric. Exp. Stn. Bull. 485, 22 p.

nis paper summarizes 6 years research relating to problems in stabilization of mine tailings ith revegetation. Laboratory, greenhouse, and field studies are discussed. Tailings are ighly variable in physical and chemical properties. Excessive soluble salts, oxidation of yrites leading to acidification, and heavy metal toxicity are problems that are covered. ailings are also deficient in plant nutrients and subject to severe wind erosion. Fifty-nine lant materials were evaluated to determine their adaptation to tailings. None showed unique daptability.

29. O'Neill, T. J., and F. S. Matter.
1976. Recycling Arizona land after copper mining. Soc. Mining Eng. AIME, reprint 76-K-336, 16 p.

630. Oxford, T. P., and L. G. Bromwell.
1977. Planning for phosphate land reclamation. In Proc., Conference on Geotechnical Practices for Disposal of Soild Waste Matter [Univ. Mich., Ann Arbor, June 13-15, 1977]. p. 715-726. Am. Soc. Civil. Eng., New York.

This paper describes considerations involved in the development of a life-of-mine plan for the disposal of wastes and the restoration of land to benefical use for a future mining tract in central Florida. The arrangement and cost of waste clay settling areas, minimization of disturbance to unmineable areas, the interface between the operation and the surrounding community, the presence of wetland areas, and the selection of reclamation techniques are among the concerns addressed.

631. Packer, P. E.
1974. Rehabilitation potentials and limitations of surface-mined land in the Northern Great Plains. USDA For. Serv. Gen. Tech. Rep. INT-14, 44 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

This survey and analysis of rehabilitation experience and potentials of the major coal and bentonite surface mines in the Northern Great Plains indicate several rather common problems. Perhaps the most common is leaving steep spoil slopes on unstable soil associations. Rilling and gullying start quickly, particularly where spoils have high sodium contents. Such erosion washes seed and fertilizer from areas that need revegetation. The author believes that almost all the surface-mined lands of the Northern Great Plains can be rehabilitated successfully. However, a large amount of basic information needs to be collected, and numerous research problems require solutions before such rehabilitation can proceed expeditiously, effectively, and economically.

632. Packer, P. E., C. E. Jensen, E. L. Noble, and others.
1979. Estimating revegetation potentials of land surface mined for coal in the West. In Ecology and resource development, vol. 1. p. 396-411. M. K. Wali, ed. Pergamon Press, New York.

633. Peplow, E. H., Jr.
1970. Western mining's land restoration efforts. Mining Congr. J. 56(9):59-63.

634. Persse, F. H.
1975. Strip-mining techniques to minimize environmental damage in the upper Missouri River Basin states. 58 p. U.S. Bur. Mines, Denver, Colo. [Available NTIS as PB-245-843.]

Geology, climate, and current land use information in the upper Missouri River Basin are presented to assist strip-mining and strip-mining land reclamation operations. Proven methods of air and water pollution control and mined land restoration are described along with untried methods and equipment for land reclamation. The semiarid climate of the upper Missouri River Basin necessitates suppression of dust for the well-being of both men and machinery. However, current air pollution control methods are expected to satisfy these needs in most instances. The prevention of water pollution at coal and lignite operations generally would include diverting surface water from the working area without increasing sedimentation or dissolved salt content, measuring all water entering and leaving the mine area, and constructing a settling basin for mine water containing sediments, which are to flow in a water course. Reclamation of strip-mined land will require a greater annual expenditure than that for air or water pollution control. Unit reclamation costs for the thick deposits are expected to be less than in other parts of the Nation. These costs are part of the production costs and should be borne by the ultimate consumer.

635. Peters, T. H.
1978. Inco Metals reclamation program. In Proc., 80th Annu. Meet., Canadian Inst. of Mining and Metallurgy [April 1978, Vancouver, B.C.]. 9 p. Can. Inst. of Mining and Metall., Vancouver, B.C.

ıe paper reviews the history of Inco Metals' reclamation program which began in 1917 with the ɔnstruction of Nickel Park. Revegetation techniques, species selection, seed mixtures, ılch, and fertilizer treatments are included. In 1974 a wildlife management plan for develop- ənt of a wildlife management area on the reclamation site was implemented.

36. Peters, W. C., ed.
1970. Mining and ecology in the arid environment. Dep. Mining and Geol. Eng., Univ. Ariz., Tucson.

37. Pommerening, E.
1976. Revegetation of the Coeur d'Alene mining district. 17 p. [AMC Mining Cov., set No. 2: Environ. Controls 1 & 2, Denver, Colo., Sep. 26-29, 1976.] Am. Mining Congr., Washington, D.C.

ıe paper describes a major revegetation program which was begun in 1974 by the Bunker Hill ɔmpany in the mine-affected area of the Coeur d'Alene mining district in northern Idaho. isturbances of two types are present within the district: tailings deposits from the concentra- ɔrs and denuded mountain slopes. The original vegetation on the mountain slopes was destroyed y forest fires. Reforestation was prevented by high concentrations of SO_2 in gaseous emissions rom the Bunker Hill Company's lead smelter and electrolytic zinc plant. The company's efforts imed at establishing vegetation at the sites of the tailings ponds within the district are ighlighted. These included soil tests, fertilization, irrigation, growth of trees and shrubs, ıd their planting.

38. Pommerening, E.
1977. Revegetation of the Coeur d'Alene mining district. Mining Congr. J. 63(3):20-23.

major revegetation program was begun in 1974 by the Bunker Hill Co. in the mine-affected rea of the Coeur d'Alene mining district in northern Idaho. Little research had been done on əavy metal mine and smelter disturbances in the West. Disturbances of two types are present ithin the district: tailings deposits from the concentrators and denuded mountain slopes. ıe original vegetation on the mountain slopes was destroyed by forest fires. Reforestation as prevented by high concentrations of SO_2 in gaseous emissions from Bunker Hill's lead nelter and electrolytic zinc plant. Greenhouse experiments were conducted to determine which ɔecies of grasses and legumes and which fertilizer application would produce the best ground ɔver.

39. Prather, J. G.
1973. Vegetative stabilization of reclaimed copper stamp-sands. M.S. thesis. Mich. Tech. Univ., Houghton. 117 p.

study to develop methods for the vegetative stabilization of a reclaimed copper stamp-sand əposit was initiated during September of 1970. Initial efforts were directed at reducing the ɔvement of surface sand and eliminating airborne dust. Approximately 30 herbaceous species lus 39 tree and shrub species have been planted on the study area. Surface stabilization reatments including fiber mulch and adhesive chemicals have successfully stabilized portions f the study area. Seedings of grasses and legumes in conjunction with the surface stabilizing gents have been less than satisfactory in developing a vegetative cover. However, the correct ixture of irrigation, organic matter additions, and fertilizer amendments in conjunction with ite amelioration techniques will produce stands of vegetation resulting in stabilization of ıe deposit.

40. Reed, J. B.
1970. Phosphate companies succeed in surface mine reclamation. 2 p. USDA Soil Conserv. Serv., Soil Conserv. Mag. (April 1970). Washington, D.C.

41. Reeder, J. D., and W. A. Berg.
1977. Plant uptake of indigenous and fertilizer nitrogen from a cretaceous shale and clay mine spoils. J. Soil Sci. Soc. Am. 41(5):919-921.

642. Research Committee on Coal Mine Spoil Revegetation in Pennsylvania.
1971. A guide for revegetating bituminous strip-mine spoils in Pennsylvania. 46 p.

643. Reynolds, J. F., M. J. Civik, and N. E. Kelley.
1978. Reclamation at Anaconda's open pit uranium mine, New Mexico. Reclam. Rev. 1(1):9-17.

644. Richardson, B. Z., E. E. Farmer, R. W. Brown, and others.
1976. Rehabilitation on a surface mined area of eastern Montana. In Fort Union Cold Field Symposium. p. 247-265. Mont. Acad. Sci., Billings.

This paper provides a comprehensive discussion on revegetation research in eastern Montana. Various soil treatments (fertilizer, mulch, no fertilizer, no mulch, topdressing, and irrigati were tested. Three different seed mixtures were used: (1) natives, (2) native introduced, anc (3) introduced species only. Results show that top-dressed treatment produces acceptable stands. Wheatgrasses are dominant in the first and second year but may fall off in the third year. There is strong evidence that native grasses will respond favorably to rehabilitation inputs at Decker coal mine.

641. Roberts, J. R.
1974. Mining and reclamation in Kentucky. In Res. and Appl. Technol. Symp. on Mined-Land Reclam., 2nd, Coal and the Environ. Tech. Conf. [Louisville, Ky., Oct. 22-24, 1974.] p. 1-4. Natl. Coal Assoc., Washington, D.C.

Surface mining of coal and of sand, stone, gravel, clay fluorspar, rock asphalt, and any othe commercially mined solid material regulations are discussed.

646. Rowell, M. J.
1977. Continued studies of soil improvement and revegetation of tailings sand slopes Norwest Soil Research Ltd. for Environmental Research, Mongr. 1977-4, 156 p. Syncru Canada Ltd.

Studies were continued in 1976 into the improvement of a 5-year-old revegetated area on a tailings sand dike by the implementation of different fertilizer programs. In June 1976 levels of available N, P, K, and S were adequate for plant growth. However, even where fertilizers were added levels of mineral N had dropped to low levels by September 1976. Plant top production early in the 1976 season was increased by application of nitrogen fertilizer durin the previous August. Continued good growth throughout the summer only occurred when extra N, P, K, and S fertilizers were added in June 1976. The most efficient use of fertilizer occurr when nitrogen was added at a rate of about 80 kg/ha or less. At the higher fertilizer applic tion rates there was a tendency for bromegrass to replace creeping red fescue as the dominant grass in the area. The accumulation of root tissues has occurred over the past 5 years to th extent that current root:shoot ratios vary from about 4:1 to 7:1. Erosion of the area was negligible in 1976.

647. Sedgley, E. F.
1974. Revegetation potential of western rangelands in the oil shale regions. In Second Research and Applied Technology Symp. on Mined-Land Reclamation Proc. [Louis ville, Ky., Oct. 22-24]. p. 29-33. J. F. Boyer, ed. Natl. Coal Assoc., Washingto D.C.

648. Shetron, S. G., and R. Duffek.
1970. Establishing vegetation on iron mine tailings. J. Soil Water Conserv. 25(6):22 230.

649. Shetron, S. G., B. M. Hamil, M. F. Jurgensen, and others.
1977. Establishing vegetation on alkaline iron and copper tailings. Mich. Dep. Nat. Resour., Geol. Surv. Div., Rep. of Investigation 17, 14 p.

arge scale field plantings commenced in the fall of 1970 and spring of 1971 to determine the otential of fine-grained alkaline iron and copper mine mill wastes for the growth of vegetation. ack of essential nutrients such as nitrogen necessitated development of a special fertilizer lend and application rates to compensate for deficiencies. Three applications the first year, wo the second, and a spring topdress each year thereafter have proven satisfactory in maintaing adequate plant growth. Excessively high levels of micronutrients such as iron in the ron tailings have not hindered plant growth. However, the same management on copper tailings as resulted in low plant survival. Severe wind and water erosion of the materials made ulching necessary. In those areas subjected to severe wind erosion, surface mulching resulted n greater plant survival.

50. Smith, R. A. H., and A. D. Bradshaw.
1972. Stabilization of toxic mine wastes by the use of tolerant plant populations. Inst. of Mining and Metallurgy, Trans. 81:A230-A237.

51. Specht, R. L.
1975. The effect of fertilizers on sclerophyll (heath) vegetation--the problems of revegetation after sand-mining of high dunes. Search, Sci. Technol. Soc. 6(11/12):459-461.

52. Stucky, D. J., and T. S. Newman.
1977. Effect of dried anaerobically digested sewage sludge on yield and element accumulation in tall fescue and alfalfa. J. Environ. Qual. 6(3):271-278.

wo rates of dried anaerobically digested sewage sludge were used in a greenhouse pot study to etermine the effect on yield, areal coverage, and element accumulation in "Ky-31" tall fescue nd alfalfa grown during a 2-year growth period, on an agricultural soil and on acid stripine spoil. The initial pH of strip-mine spoil was approximately 3.5, and sludge additions of 14 and 627 metric tons/ha raised the pH to 5.5 and 6.0, respectively. Sludge applications of 14 and 627 metric tons/ha significantly increased yields of plants grown on agricultural oil. On strip-mine spoil, yields of tall fescue and alfalfa were significantly increased at he application rate of 627 metric tons/ha. In all treatments the yields of alfalfa were reater than that of tall fescue, although the areal coverage of fescue exceeded that of lfalfa. Increasing rates of sewage sludge decreased the amount of Mn, Zn, Ni, and Cd accumuated in tall fescue and alfalfa in strip-mine spoils. Copper accumulation was not affected y application rates.

53. Summer, R. M.
1978. Sand and gravel reclamation factors, Colorado County, Texas. Mining Eng. 30(1):45-47.

54. Tayki, S. K., M. H. Rowell, W. B. McGill, and others.
1977. Reclamation and vegetation of surface mined areas in the Athabasca tar sands. Environ. Res. Monogr. 1977-1, 170 p. Syncrude Canada Ltd.

ne of the major environmental problems which arises with surface mining of the oil sands in he Fort McMurray-Fort MacKay area of Alberta is the permanent loss of the natural vegetation nd the drastic change in the soils that supported it. It has been estimated that with a roduction target of 1 million barrels of crude oil per day approximately 2,000 acres of land ill have to be cleared every year. Most of the disturbed areas eventually must be vegetated gain; these include the overburden piles and the tailings sand. In vegetating such areas everal problems such as salinity, oil, low fertility, erosion, and unfavorable soil reaction ust be contended with. There has been some success in the general vegetation program on the reat Canadian Oil Sands Ltd. lease, but the problems listed above still have to be studied nd solutions for them found. The following research projects were undertaken to solve some f these problems.

655. Terwilliger, C., C. W. Cook, and P. L. Sims.
1974. Natural and artificial rehabilitation of disturbed sites in an oil shale area. In Surface rehabilitation of land disturbances resulting from oil shale development, executive summary. p. 17-25. C. W. Cook, ed. Colo. State Univ., Fort Collins, Environ. Resour. Cent., Infor. Series 11, 56 p.

656. Tresler, R. L.
1974. Strip mine reclamation in Wyoming. In Second Research and Applied Technology Symp. on Mined-Land Reclamation Proc. [Louisville, Ky., Oct. 22-24]. p. 22-28. Natl. Coal Assoc., Washington, D.C.

Various techniques being used in mine reclamation throughout Wyoming are discussed and key steps in revegetating are systematically presented.

657. USDA Soil Conservation Service.
1963. Guide for classifying and revegetating strip-mine spoil in Pennsylvania. 23 p. USDA Soil Conserv. Serv., Harrisburg, Penn.

658. Van Kekerix, L. K., R. W. Brown, and R. S. Johnston.
1979. The effect of mine spoil treatments on seedling water relations. USDA For. Serv. Res. Note INT-262, 17 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

659. Verma, T. R., K. L. Ludeke, and A. D. Day.
1977. Rehabilitation of copper mine tailing slopes using municipal sewage effluent. Hydrol. and Water Resour. in Ariz. and the Southwest 7:61-68.

660. Vivyurka, A. J.
1975. Rehabilitation of uranium mines tailings areas. Can. Mining J. 96(6):44-45.

661. Vories, K. C., and P. L. Sims.
1977. The plant information network: vol. I. A user's guide. p. 1-56. Western Energy and Land Use Team, Off. Biol. Serv., U.S. Fish and Wildlife Serv., Fort Collins, Colo.

662. Vories, K. C., and P. L. Sims.
1977. The plant information network: vol. II. Reclamation and PIN in northwestern Colorado. p. 57-108. Western Energy and Land Use Team, Off. Biol. Serv., U.S. Fish and Wildlife Serv., Fort Collins, Colo.

663. Vories, K. C., and P. L. Sims.
1977. The plant information network: vol. III. Reclamation and PIN in the Powder River Basin of Montana and Wyoming. p. 109-160. Western Energy and Land Use Team, Off. Biol. Serv., U.S. Fish and Wildlife Serv., Fort Collins, Colo.

664. Ward, R. T., W. Slauson, and R. L. Dix.
1974. The natural vegetation in the landscape of the Colorado oil shale region. In Surface rehabilitation of land disturbances resulting from oil shale development, executive summary. p. 9-17. C. W. Cook, ed. Colorado State Univ., Fort Collins, Environ. Resour. Cent., Infor. Series 11, 56 p.

665. Watkin, E. M., and J. E. Winch.
1973. Composed organic wastes, sewage sludges, and rock phosphate for amelioration of acid uranium mine tailings. In Proc., Int. Conf. on Land for Waste Management [Ottawa, Can., Oct. 1973]. p. 48-56.

666. Wells, E.
1969. Voluntary land reclamation in the Florida phosphate industry. Proc. Mining Environ. Conf. [Rolla, Mo., Apr. 16-18]. p. 110-115. Univ. Missouri, Rolla.

ork done by phosphate mining industry in Florida in reclaiming the land after mining out of hosphate ore is reported.

67. Western Miner.
1973. Summary of vegetation programme on lead-zinc tailings pond. Western Miner 46(8):32-33.

68. Wienke, C. L., and D. R. Dreesen.
1977. Ecological investigation of rehabilitation of uranium mill tailings of the southwestern United States. Los Alamos Sci. Lab. Progr. Rep. W7405, 77 p.

69. Willard, B. E.
1979. Plant sociology of alpine tundra of Trail Ridge, Rocky Mtn. Nat'l. Park, Colorado. Colo. Sch. Mines, Monograph, 119 p. [ISSN0010-1753.]

70. Williams, B. D., and P. E. Packer.
1979. Sewage sludge and other materials as amendments for revegetation of spent oil shale. In Proc., Symp. on Rehabilitation of Drastically Disturbed Land [Philadelphia, Penn., March 1977]. p. 353-358.

f large-scale production of oil from these western shales becomes a reality, and it almost ertainly will, vast quantities of spent shale will be produced and will require disposal. tabilization of these disposal sites to control erosion and to prevent or to reduce degradaion of water quality is a necessary land management objective. Some research has already een done, with varying degrees of success, to develop measures for revegetating spent shale. ittle has been done, however, to improve the properties of this spent shale for plant growth y using as amendments readily available, organic waste materials from sources other than ined areas. Use of such amendments might help the establishment of vegetation on spent shale s well as provide a profitable way to dispose of these organic wastes. For these reasons, ioassay studies were undertaken to determine the growth responses of a salt-tolerant plant, all wheatgrass (*Agropyron elongatum*), grown in spent shale treated with various combinations f leaching, fertilizer, and organic amendments. Results of these studies show that organic aste amendments effectively enhance plant growth in spent oil shale and that some amendments re significantly more effective than others.

71. Wiseman, T.
1978. Hitting pay dirt with pine seeds: strip mines reforested. Mining Congr. J. 64:59-60.

his article discusses the benefits of direct seeding of steep/rocky strip-mined land with ine seed that has been treated with effective bird and rodent repellents. In many places here soil conditions are good for pine tree establishment, pines cannot be planted (due to opography, etc.). These are prime areas for direct, aerial seedings. Results can be quite ood.

72. Zuck, R. H., and L. F. Brown, eds.
1976. Proc., High Altitude Revegetation Workshop No. 2. Colo. State Univ., Environ. Resour. Cent., Infor. Series 21, 120 p.

apers include such topics as: reclamation laws, training reclamation personnel, plant aterials (collection of wildland seed, use of containerized seedlings, shrubs, and trees), stablishment methods, etc.

M. Environmental Effects, Impacts, Baseline Data

Section M includes environmental impact statements, "state-of-the-art" publications, and those citations that provide baseline data on broad environmental effects of surface mining.

673. Ackerman, D. H.
1973. Environmental impact study: a tool for sound mineral development. Mining Congr. J. 59(12):16-22.

As a result of some 8 years of exploratory work, the American Metal Climax Co. has ascertained that a copper-molybdenum deposit located in northwest Wyoming, near an old mining camp of Kiroin has sufficient Cu-Mo mineralization to warrant its consideration as an open pit mine. Paper discusses the scope of an environmental impact study, which will have to be completed with cooperation of local authorities before a final decision is taken. Some more significant elements of the study are: reclamation of the vegetation at the altitude of open pit from 8,000 to 11,000 ft; waste and tailings disposal in a high, narrow valley; water pollution by mine drainage and ore treatment plant; housing, etc.

674. Atomic Energy Commission.
1972. Leasing of AEC controlled uranium bearing lands, Colorado, Utah, New Mexico. 203 p. Atomic Energy Comm., Washington, D.C. [Available NTIS as EIS-CO-72-5340-F.]

The statement has been prepared in support of the AEC's administrative action to lease about 25,000 acres of uranium bearing lands. With strict enforcement of stipulations, the mining operations are expected to have a minimal impact on the environment.

675. Automation Industries, Inc.
1977. Energy/Environment II. Proceedings of Second National Conference on the Interagency R and D Program [Washington, D.C., June 6-7]. 514 p. Automation Industries, Inc., Silver Springs, Md. [Available NTIS as PB-277 917/1ST.]

All papers presented at this conference, along with discussion from question and answer periods, are included in the text. Topics discussed include the following: fuel processing; utility and industrial power; extraction and beneficiation; integrated technology assessment; health effects; atmospheric transport and fate; measurement and monitoring; ecological effects

676. Box, T. W.
1973. The energy crisis and the fate of strip mine lands. Utah Sci. 35(4):117-120.

677. Cammarota, V. A., Jr.
1978. Zinc. 33 p. U.S. Bur. Mines, Washington, D.C. [Available NTIS as PB-283 732/6ST.]

The zinc industry is reviewed in terms of structure, organization, and geographic distribution The geology of zinc deposits, resources, and mining and smelting of zinc are briefly described The economic and environmental factors associated with zinc extraction are discussed. The report gives an overview of the uses of zinc in transportation, construction, electrical equipment, machinery, paint, chemicals, and rubber products, and forecasts the use of zinc to the year 2000. The U.S. demand in 2000 is forecast to be about 2.2 million tons, representing an annual growth rate of 2.0 percent and 9.1 million tons for the rest of the world at an annual growth of 2.1 percent. While U.S. mine production is expected to reach 800,000 tons, the nation will continue to rely on imports for a significant portion of its supply. Reserves were considered sufficient to supply anticipated world demand for primary zinc.

678. Clark, D. A.
1974. State-of-the-art: uranium mining, milling and refining industry. 123 p. Robert S. Kerr Environ. Res. Lab., Ada, Okla. [Available NTIS as PB-235 557/6.]

79. Colorado University.
1971. An interdisciplinary study of transport and biological effects of molybdenum in the environment. 133 p. Colo. Univ., Boulder. [Available NTIS as PB-222 821/1.]

he purpose of the research effort is to examine the release and transport of molybdenum and
ts subsequent impact on man and his environment. This study has particular relevance to
enver and the surrounding mountainous and agricultural areas which are target areas for
bnormally high levels of molybdenum in streams draining the mountainous area to the west of
enver. The study consists of an interdisciplinary effort which involves: (1) determining
he sources of the molybdenum in surface waters, (2) determining the rates and modes of trans-
ort, (3) determining the targets, (4) determining the biological cycling, (5) developing
nalytical tools, (6) examining the biological effects particularly with regard to calcium
ransport and energy transduction, (7) examining the potential economic ramifications of the
tudy, (8) studying various aspects of the public perception of who the public holds respon-
ible and how willing the public is to participate in the solution of a possibly hazardous
ituation.

80. Cook, C. W.
1974. Surface rehabilitation of land disturbances resulting from oil shale development. Final rep., phase I. 255 p. Colo. State Univ., Fort Collins.

81. Cook, C. W., R. C. Austin, V. W. Brown, and others.
1973. Study team on environmental problems associated with fuel materials. 106 p. Mass. Inst. Tech. Press, Cambridge, Mass.

82. Conkle, N., V. Ellzey, and K. Murthy.
1974. Environmental considerations for oil shale development. Battelle Columbus Labs, Ohio.

esults of a preliminary literature study of the environmental considerations in the develop-
ent of an environmentally acceptable oil shale industry are presented. The following seven
ifferent areas are included in the study: oil shale deposits; in-situ retorting; ex-situ
etorting; retorted shale disposal; mining, handling, and pretreatment processes; other environ-
ental considerations; and product treatment and usage. Research and development needs required
o eliminate inadequacies in the data base necessary to evaluate potential environmental
roblems are noted. The report provides an overview of the anticipated oil shale industry,
ncluding the magnitude of the resources available and the likely technical and environmental
roblems to be encountered. Specific technologies likely to be employed in the mining, oil
xtraction, and on-site upgrading process are also identified.

83. Conkle, N., V. Ellzey, and K. Murthy.
1974. Environmental considerations for oil shale development. Final report, Jan.-May 1974. 133 p. Battelle Columbus Labs, Ohio. [Available NTIS as PB-241 942.]

n overview is provided of the anticipated oil shale industry, including the magnitude of the
esources available and the likely technical environmental problems to be encountered. Specific
echnologies likely to be employed in the mining, oil extraction, and on-site upgrading processes
re also identified. The status of development of these technologies and their potential
conomic, resource, and environmental impacts upon the oil shale resource regions and the
ation as a whole are also described.

84. Crawford, K. W., and others.
1977. A preliminary assessment of the environmental impacts from oil shale developments. 174 p. TRW Environ. Eng. Div., Redondo Beach, Calif. [Available NTIS as PB-272 283.]

85. Davis, G.
1978. Oil shale. In Reclamation of drastically disturbed lands. p. 609-618. F. W. Schaller and P. Sutton, eds. Agron. Soc. Am., Crop Sci. Soc. Am., Soil Sci. Soc. Am., Madison, Wis.

This paper gives a summary of oil shale: what it is, where it is found, how it is mined, and problems in oil shale development. Also included is a section on reclamation of oil shale. Stability, hydrology, and revegetation of spent oil shale are discussed.

686. Dawson, A. D.
1974. Earth removal and environmental protection. Environ. Affairs 3:166-187.

687. Dinneen, G. U., and G. L. Cook.
1975. Oil shale and the energy crisis. In Perspectives on energy. p. 377-385. L. C. Ruedisili and M. W. Firebaugh, eds. Oxford Univ. Press, London. 527 p.

688. Doherty, F. J.
1974. Environmental factors involved in applying for a zoning permit to extract sand and gravel--a case history. 13 p. Natl. Sand and Gravel Assoc., Washington, D.C.

689. Dole, H. T. Beard, J. Bredehoeft, and others.
1974. Report of the committee on environment and public planning. Newsl. Geol. Soc. Am. Suppl. 9(4):1-8.

A review on technology and environmental effects of developing oil shale in the Green River formation.

690. Donnelly, W. H.
1974. Impact of energy shortages on U.S. environmental standards. 52 p. Library of Congress, Washington, D.C. [Microfiche number 74-78.]

The recent energy shortages in the United States have created numerous problems, including environmental ones. These environmental issues involve extraction of fuels from nature, thei use, and the siting of large energy facilities. All have generated controversy, and the present situation has caused many to question the desirability of controls to protect the environment from effects of supplying and using fuels and energy. The report examines energy variances and NEFA effects of the energy shortage on air quality, nuclear power, power plant siting, outer continental shelf development, and surface mining of coal and oil shale.

691. Dorset, P., D. Myers, and T. Parker.
1977. Advanced fossil fuel and the environment: an executive report. U.S. Environ. Protec. Agency, Off. Res. and Develop., EPA 60019-77-013. Cincinnati, Ohio.

692. Ellis, J. E., and W. J. Parton.
1978. Impact of strip-mine reclamation practices: a simulation study. 329 p. Wester Energy and Land Use Team, Off. Biol. Serv., U.S. Fish and Wildlife Serv., Fort Collins, Colo.

693. Engineering and Mining Journal.
1970. A national western mining conference--its uranium, pollution, and technology. Eng. and Mining J. 171(4):74-75.

694. Falk, M. R., M. D. Miller, and S. M. Kostivk.
1973. Biological effects of mining wastes in the Northwest Territories. Environ. Can., Fish. and Marine Serv., Tech. Rep. Series CEN/T-73-10.

Studies to determine the effect of mine wastes on aquatic biota are discussed in this paper. Water quality, effluent toxicity, metal contamination, invertebrates, fish, and benthos divers were assessed at each study site.

695. Frazier, N. A.
1976. Production and processing of U.S. tar sands: an environmental assessment, final report. 92 p. Battelle Columbus Labs, Ohio. [Available NTIS as PB-266 266/6GA.]

696. Gage, S. J.
1975. A federal energy/environmental research and developmental program. In Energy Technology II: Second Energy Technology Conference Proc. [Washington, D.C., May 12-14.] p. 242-270. T. F. P. Sullivan, ed. Government Institutes, Inc., Washington, D.C. 344 p.

697. Gage, S. J.
1977. Appalachian mineral resource development: environmental factors. 17 p. Mitre Corporation, McKean, Va. [Available NTIS as PB-274 107/2GA.]

698. Garofalo, D., and F. J. Wobber.
1974. Aerial-photographic analysis of the environmental impact of clay mining in New Jersey. Photogrammetria 30(1):1-19.

Black-and-white, color, and color-infrared photography at 1:20,000 scale or larger provide useful data for monitoring the environmental effects of surface mining as demonstrated, following study of surface clay mining. Investigations using high-altitude color and color-infrared photography at scales of 1:80,000 to 1:120,000 provide an efficient technique for inventorying large-surface mining operations or for rapid statewide mining studies.

699. Givens, B. M., and C. A. Boyd.
1976. Energy Research Information System, vol. 1, No. 1. 238 p. Old West Regional Commission, Billings, Mont. [Available NTIS as PB-276 851/3ST.]

The goal of the Energy Research Information System (ERIS) is to provide an inventory of energy-related programs and research activities from 1974 to the present in the States of Montana, Nebraska, North Dakota, South Dakota, and Wyoming. Areas of research covered include coal, reclamation, water resources, environmental impacts, socioeconomic impacts, energy conversion, mining methodology, petroleum, natural gas, oil shale, renewable energy resources, nuclear energy, energy conservation, and land use. Each project description lists title, investigator(s), research institution, sponsor, funding, time frame, location, a descriptive abstract of the research, and reports and/or publications generated by the research. All projects are indexed by location, personal names, organizations, and subject keywords. This report contains 300 project references.

700. Givens, B. M., and C. A. Boyd.
1976. Energy Research Information System, vol. 1, No. 2. 108 p. Old West Regional Commission, Billings, Mont. [Available NTIS as PB-276 852/1ST.]

Areas of research covered include coal, reclamation, water resources, environmental impacts, socioeconomic impacts, energy conversion, mining methodology, petroleum, natural gas, oil shale, renewable energy resources, nuclear energy, energy conservation, and land use. Each project description lists title, investigator(s), research institution, sponsor, funding, time frame, location, a descriptive abstract of the research, and reports and/or publications generated by the research. All projects are indexed by location, personal names, organizations, and subject keywords. This report contains 93 project references and is in addition to volume 1, No. 1 (portions of this document are not fully legible).

701. Givens, B. M., and C. A. Boyd.
1976. Energy Research Information System, vol. 1, No. 3. 126 p. Old West Regional Commission, Billings, Mont. [Available NTIS as PB-276 853/9ST.]

Areas of research covered include coal, reclamation, water resources, environmental impacts, socioeconomic impacts, energy conversion, mining methodology, petroleum, natural gas, oil shale, renewable energy resources, nuclear energy, energy conservation, and land use. Each project description lists title, investigator(s), research institution, sponsor, funding, time frame, location, a descriptive abstract of the research and reports and/or publications generated by the research. All projects are indexed by location, personal names, organizations, and subject keywords. This issue contains 146 project references and is in addition to volume 1, No. 1 and No. 2.

702. Givens, B. M., and C. A. Boyd.
1976. Energy Research Information System, vol. 1, No. 4. Cumulative indexes. 98 p. Old West Regional Commission, Billings, Mont. [Available NTIS as PB-276 854/7ST.]

This cumulative index includes a State location index, an organization index, and a subject keyword index incorporating the indexes from Energy Research Information System (ERIS), volume 1, Nos. 1, 2, and 3. This issue plus the first three ERIS reports comprise a set of 539 research project references for the States of the Old West Region--Montana, Nebraska, North Dakota, South Dakota, and Wyoming.

703. Hanson, W. C., and F. R. Meira, Jr.
1977. Long-term ecological effects of exposure to uranium. Los Alamos Sci. Lab. Progr. Rep. W7405-ENG, 34 p.

704. Hays, R. M.
1974. Environmental, economic, and social impacts of mining copper-nickel in northeast Minnesota. 149 p. Dep. Civil and Mining Eng., Minn. Univ., Minneapolis. [Availabl NTIS as PB-204 466/3ST.]

The Culuth Gabbro Complex in northeastern Minnesota possibly contains a significant domestic copper resource and the Nation's largest nickel resource. Exploration has discovered large low-grade copper-nickel (Cu-Ni) deposits between Hyt Lakes and the Boundary Water Canoe Area. The mining and processing of Cu-Ni will have environmental, economic, and social impacts. The purpose of the study is to relate major environmental, economic, and social considerations to various aspects of Cu-Ni extraction. An open pit and two underground (block caving and open sloping with backfilling) models were developed to generate information on the impact of Cu-Ni extraction. Important considerations having environmental, economic, and social impacts during various aspects of Cu-Ni extraction are identified and defined. These aspects are exploration, development, mining, beneficiating, smelting, industrial, energy, climatic, resource, water, air emission, waste disposal, employee, tax and royalty, transporation, and community considerations.

705. Hendricks, D. W., and H. C. Ward.
1976. Environmental analysis of an oil shale industry in the upper Colorado region. In Oil shale. p. 215-234. T. F. Yen and G. V. Chilingar, eds. American Elsevier Publishing Company, Inc., New York. 292 p.

706. Henry, C. D.
1976. Land resources inventory of lignite strip-mining areas, East Texas: an applicati of environmental geology. Univ. Texas, Austin, Bur. Econ. Geol., Geol. Circ. 76-2, 28 p.

707. Howe, C. W., and others.
1976. Integrated socioeconomic-hydrosalinity-air quality analysis of shale oil and coal development in Colorado. In EPA Conference on Environmental Modeling and Simulation Proc. [Cincinnati, Ohio, Apr. 19-22]. p. 34-35. W. R. Ott, ed. Booz-Allen Applied Research, Inc., Chicago, Ill. 861 p. [Available NTIS as PB-257 142/OGA.]

708. Hunkin, G. G.
1975. The environmental impact of solution mining for uranium. Mining Congr. J. 61(10):24-27.

Compared with most other mining systems, uranium solution mining has a negligible effect on such environmental factors as surface disturbance, interference with natural groundwater quality and distribution, and aerial discharge of radionuclides. Borehole mining by the in-situ leaching of uranium from naturally permeable deposits enables the economic exploitatio of these reserves under current production-cost, selling-price conditions. Engineered well systems and controlled input/production flow rates, combined with full recirculation systems that maintain constant fluid volumes in the mineralized formations, result in ntainment of leach solutions within the operating area. The very dilute leach solutions, mpatible with natural groundwaters, ensure that no environmental damage results, even if loss of control occurred. Virtual elimination of operator hazards, waste diposal, and land habilitation costs help in reducing overall costs. The reduction in the number of stages processing results in substantial savings in energy, operating costs, labor requirements, pital, and lead times.

9. Ichiye, T.
   1978. Deep Ocean Mining Environmental Study (DOMES). Mid-ocean aquaculture - benefits of deep ocean mining operation. Unpubl. ms. No. 30, 63 p. Natl. Oceanic and Atmospheric Admin., Seattle, Wash. [Available NTIS as PB-284 744/0ST.]

e possibility of developing a midocean aquaculture in the vicinity of a deep ocean mining oject is examined. The Deep Ocean Mining Operation (DOMO) will produce the vertical velocity mparable to the natural upwelling in the midocean. Actually DOMO is more efficient in inging the bottom water to the surface, because in natural conditions the vertical eddy iffusivity sometimes counteracts upwelling in upward transport of the bottom water. Most rine biologists consider that the primary productivity of the ocean is mainly enhanced by trients brought near the surface from the bottom by upwelling or by other processes. Therere, DOMO might be able to increase the primary productivity of the oceanic region which is ther barren in the natural conditions, if it is carried out with careful planning. Further vestigation of the potentials for aquaculture in the DOMO area is proposed.

10. Information Systems Technical Laboratory, Federation of Rocky Mountain States, Inc.
   1977. Natural resource geographic data bases for Montana and Wyoming. 78 p. U.S. Fish and Wildlife Serv., Biol. Serv. Prog., Fort Collins, Colo.

11. Janes, D. C., and others.
   1977. Monitoring environmental impacts of the coal and oil shale industries: research and development needs. 207 p. Radian Corporation, Austin, Tex. [Available NTIS as PB-266-292/2GA.]

12. Jones, M. J., ed.
   1975. Minerals and the environment. 103 p. Inst. of Mining and Metallurgy, London.

rty-one papers presented at this symposium discuss various methods by which environmental mage in mining can be substantially reduced, if not entirely eliminated. Preference is iven to papers that indicate how such damage could be avoided rather than those that merely escribe environmental damage that had already taken place. The subjects discussed include: nvironmental aspects of the North American mining industry; surveillance of mining operations y satellite (ERTS-1); water reuse in Canadian ore-concentration plants; pollution control and pgrading of mineral finds with bitumen; open cast coal mining; working, restoration, and eclamation; ecological approach to mining waste revegetation; environmental control in iron re sintering; some practical aspects of dust control in coal mining; and mining subsidence nd the environment. Selected articles are indexed separately.

13. Jumars, P. A.
   1977. Deep Ocean Mining Environmental Study (DOMES). Potential environmental impact of deep-sea manganese nodule mining: community analysis and prediction. Unpubl. ms. No. 13, 54 p. Natl. Oceanic and Atmospheric Admin., Seattle, Wash. [Available NTIS as PB-283 152/7ST.]

ch of the progress in this study is summarized in the two attached manuscripts. The first evelops spatial autocorrelative methods for ecological application, and the second establishes heir relevance to analysis and descriptions of deep-sea benthic (baseline) data. The initial mpact and the rate and degree of recovery depend on the spatial and temporal scales both of he disturbance and of the segment of the community that has not been disturbed. The answers hange not only between communities with differing species compositions but also within the ame community as the pattern and extent of the disturbed area changes. None of these questions an be adequately answered before monitoring of mining effects begins.

714. Kallus, M. F.
1975. Environmental aspects of uranium mining and milling in South Texas. 7 p. Surveillance and Anal. Div., Environ. Protec. Agency, Houston, Tex. [Available NTIS as PB-266-318/5GA.]

Recent investigations of uranium mining and milling operations in the Grants Mineral Belt of New Mexico found serious environmental problems to be associated with these activities. The purpose of this investigation was to determine whether or not similar problems existed in the South Texas uranium belt. The investigation showed that these problems did not exist. Activities included in the investigation were (1) a literature search to gather background informati (2) a search of the files of State environmental regulatory agencies to assemble pertinent data; (3) an aerial and surface reconnaissance of the area involved; and (4) discussions with involved persons in both the governmental and private sectors.

715. Larson, W. C.
1978. Uranium in situ leach mining in the United States. U.S. Bur. Mines Infor. Circ. 8777, 68 p. Washington, D.C.

716. Lawver, J. E., W. O. McClintock, and R. E. Snow.
1978. Beneficiation of phosphate rock--a state-of-the-art review. Min. Sci. Eng. 1(4):278-294.

This paper presents the production statistics, the location, ore type, and process methods of beneficiation used for the major phosphate deposits of the world. A new process under development by International Minerals and Chemical Corporation for beneficiating sedimentary dolomiti phosphate is briefly described. Beneficiation technology of phosphate ore has progressed considerably in the past decade, and the industry has developed methods of processing deposits as low as 10 to 15 percent bone phosphate of lime. The major problems facing the industry are the development of new economic mining methods for handling deep deposits, and the constantly increasing burden of regulatory agencies to meet rigorous environmental standards and eventual to process ore with zero water discharge from the beneficiation plant.

717. Li, T. M.
1978. Southeastern Idaho phosphate mining: how an environmental impact statement distorts growth plans. Mining Eng. 30(1):25-28.

718. McDonald, A.
1974. Shale oil: an environmental critique. Center for Science in the Public Interest Washington, D.C. Oil Series III, 62 p.

719. Masuda, J., and T. Yamamoto.
1971. Studies on environmental contamination by uranium, 2. Absorption of uranium on soil and its desorption. J. Rad. Res. 12:94-99.

720. Merritt, R. C.
1972. Environment. Mining Eng. 24(2):97-101.

Pollution problems troubling the metallurgical industry are presented. With the introduction of new SO_2 emission standards it became apparent that existing technology available to nonferr smelters cannot achieve 94 percent control with the government's estimate of $108 million. The copper industry alone would achieve only 85 percent control at a cost approaching $600 million. It is concluded that without huge capital investments for new production technology, the pollution standards cannot be met by nonferrous smelters. Although the paper deals primar with SO_2 emissions, several case histories present facts on acid mine drainage water treatment metal recovery processes, tailings stabilization, and metals reclamation from refuse.

721. Meyers, D. L.
1977. Environmental impacts of oil shale development. 34 p. Stanford Research Instit Menlo Park, Calif. [Available NTIS as PB-276 617/8WN.]

2. Mining Engineering.
1971. Mineral industry vs. ecology. Mining Eng. 23(8):51-60.

l aspects of human environment effectively connected with the mineral industry are discussed. eumoconiosis as a result of coal mining is under control in a modern mine, however it is ill a threat as is the case with silicosis in metal mines. Instrumentation protecting ople from these hazards is described. Basic ways in which surface mining disturbs the land e spoil banks, high walls, toxic soil, and waste disposal. Results of recent Kennecott ilings stabilization tests are presented. Water pollution problems are in urgent need for tention, particularly in metal industries. Magnetic agglomeration seems to be a promising thod for classification and separation of metallics in solid wastes, as well as in treatment steel industry waste waters. Air pollution control measures are also presented.

23. Montana Department of State Lands.
1977. Bentonite mining related problems in the northwestern states. 94 p. Mont. Dep. state Lands, Helena.

24. Narayan, K., and P. J. Rand.
1977. Environmental considerations in uranium solution mining. Am. Inst. of Mining, Metallurgical and Petroleum Eng., Soc. Mining Eng., Trans. 262(2):117-119.

25. National Academy of Sciences.
1975. Mineral resources and the environment. 348 p. Natl. Acad. Sci., Washington, D.C.

is report studies the general issues involved with the continued availability and efficient e of our minerals and mineral resources: demand, supply, technology, and environmental pact of production. Among the topics discussed are technological opportunities in the terials cycle to offset shortages; a conservation ethic with regard to our resources; capital, npower, and time constraints on technology; world resources of petroleum and natural gas, iscovered reserves and undiscovered recoverable resources; production of copper; environmental ffects of coal production and use; mine safety and health; effects of sulfur pollutants on e public health; evaluation of demand projections; methods for estimating minerals resources d reserves.

26. Nerkervis, R. J., and J. B. Hallowell.
1976. Metals mining and milling process profiles with environmental aspects. 318 p. Battelle Columbus Labs, Ohio. [Available NTIS as PB-256 394/8ST.]

he report describes the environmental aspects of metals mining and milling (concentration perations in the U.S.). The metals include Al, So, Be, Cu, Au, Fe, Pb, Zn, Hg, Mo, Ni, Pt, he rare earth metals, Ag, Ti, W, U, and V. The types of environmental impacts associated ith operations from mining through production of concentrate are described in general terms. he number and locations of plants, the names of producing companies, production levels, and ther characterisitics of the industry are presented. Each unit process is described in terms f function, input materials, operating conditions, utilities and energy use, and waste streams. he descriptions of unit processes identify waste streams in terms of emissions to the air, ater effluents, and solid wastes disposed to the land. The approximately 185 unit operations escribed include mining, dredging, crushing, flotation, leaching, sintering, and nodulizing. he most common waste streams are dusts from mining and crushing operations, liquid streams rom mine drainage, flotation operations, tailings ponds, and leach operations.

27. Newport, B. D., and J. E. Moyer.
1974. State-of-the-art: sand and gravel industry. 46 p. Robert S. Kerr Environ. Res. Lab., Ada, Okla. [Available NTIS as PB-236 147/5ST.]

n overview is presented of the sand and gravel industry in the United States and its relationhip to the environment. The fate and effects of sediment generated by this surface mining ctivity on the benthic, planktonic, and fish communities of waterways are discussed in detail. roblems of the sand and gravel industry, types of operations, status of current treatment echnology, and legislation affecting the industry are reviewed.

728. Nuclear Regulatory Commission.
1977. Bear Creek Project (Converse County, Wyoming). 470 p. Draft environmental statement. Nuclear Regulatory Comm., Washington, D.C. [Available NTIS as NUREG-0129.]

The Bear Creek Project consists of certain mining and milling operations involving uranium ore deposits located in Converse County, Wyo. Mining of uranium from six known ore bodies will take place over a period of 10 years (estimated); a mill with a nominal capacity of 1,000 tons per day of ore will be constructed and operated as long as ore is available. The waste materi (tailings) from the mill, also produced at a rate of about 1,000 tons per day, will be stored on-site in an impoundment. The project would convert about 2,700 acres from grazing use to mining and milling activities for a period of about 10 years. Mining activities would disturb (and remove vegetation from) a total of about 1,600 acres but, because of ongoing reclamation efforts, maximum acreage disturbed at any one time would be about 1,000 acres, with the averag about 650 acres. An estimated 185 acres of highways and water remaining after reclamation would be lost to agricultural production. The milling activities would disturb about 430 acres; 330 of these would be reclaimed after operations cease, but the 100-acre tailings area must be considered unavailable for further productive use. Water will be removed from aquifer at about 1,000 gal/min (range 600 to 2,000 gal/min) by mine dewatering and mill operations. Long-term effects on groundwater are expected to be minor. Surface water will not be affected by normal operations. There will be no discharge of liquid or solid effluents from the mill. Discharges to air will be small and the effects negligible. The total dose rate to the bone is 1.1 mrem/y, and the whole-body-dose rate is computed to be 0.04 mrem/y.

729. Nuclear Regulatory Commission.
1977. Bear Creek Project, final environmental statement. 472 p. Nuclear Regulatory Comm., Washington, D.C. [Available NTIS as DOCKET-408452-1.]

The Bear Creek Project consists of certain mining and milling operations involving uranium ore deposits located in Converse County, Wyoming. Mining of uranium from nine known ore bodies will take place over a period of 10 years (estimated); a mill with a nominal capacity of 1,000 tons per day of ore will be constructed and operated as long as ore is available. The waste material (tailings) from the mill, also produced at a rate of about 1,000 tons per day, will be stored on-site in an impoundment. Environmental impacts and adverse effects are summarized

730. Nuclear Regulatory Commission.
1977. Draft environment statement related to operation of Moab uranium mill (Grand County, Utah). 135 p. Nuclear Regulatory Comm., Washington, D.C. [Available NTIS as DOCKET-403453-1.]

This draft environmental impact statement was prepared by the staff of the Nuclear Regulatory Commission and issued by the Commission's Office of Nuclear Material Safety and Safeguards. The proposed action is the continuation of Source Material License SUA-917 issued to Atlas Corporation for the operation of the Atlas Uranium Mill in Grand County, Utah, near Moab (Docket No. 40-3452). This authorizes a 600-ton (450-t) per day acid leach circuit (for recovery of vanadium as well as uranium) and a 600-ton (450-t) per day alkaline leach circuit (for other ores, including copper-bearing ores).

731. Nuclear Regulatory Commission.
1977. Sweetwater Uranium Project; draft environmental statement. 197 p. Nuclear Regulatory Comm., Washington, D.C. [Available NTIS as DOCKET-408 584-1.]

The proposed action is the issuance of a Source Material License to Minerals Exploration Company for the construction and operation of the proposed Sweetwater Uranium Mill with a nominal capacity of 3,000 tons ($2.7\text{x}10^{6}$ kg) per day of uranium ore in Wyoming. The applicant proposes also to construct a heap-leaching and resin ion-exchange facility to extract uranium from low-grade ores and mine water. Impacts to the area due to the operation of the Sweetwate Uranium Mine/Mill Project will result in: alterations of up to 2,200 acres by the mill, mine pit area, and roads, and about 3,450 acres of Battle Spring Flat to be inundated by mine dewatering operations; increase in the existing background radiation levels; socioeconomic effects on Rawlins and other nearby areas; and tailings from the mill will be produced at a

te of about 3,000 tons ($2.7x10^6$ kg) per day and will be stored on-site in a lined impoundment. nditions for the issuance of the license are given.

2. Nuclear Regulatory Commission.
1978. Draft environmental statement related to the United Nuclear Corporation Morton Ranch, Wyoming uranium mill. 206 p. Nuclear Regulatory Comm., Washington, D.C. [Available NTIS as NUREG-0439.]

3. Nuclear Regulatory Commission.
1978. Draft environmental statement related to operation of Wyoming Mineral Corporation Irigary solution mining project. 180 p. Nuclear Regulatory Comm., Washington, D.C. [Available NTIS as NUREG-03999.]

4. Radcliff Materials.
1972. A study of the effects of gravel dredging on the upper Alabama River near Parkers Island, Montgomery and Elmore Counties, AL. 26 p. Radcliff Materials, Mobile, Ala.

5. Radian Corporation.
1975. A western regional energy development study: primary environmental impacts, vol. II. 771 p. Radian Corp., Austin, Tex. [Available NTIS as PB-246 265/3ST.]

e report examines the primary environmental impacts of 38 energy resource development enarios: the air and water emissions, solid waste, and land requirements of a plant or ocess. Projected ground level ambient concentrations of pollutants are compared with Federal d State standards. Scenarios include all aspects of development: extraction, conversion, d transportation to the point of end use.

6. Rajaram, V., T. A. Kauppila, and R. L. Bolmer.
1978. Oil shale mining and the environment. Mining Eng. 30(4):360-363.

perimental mining of oil shale, to date, has been conducted only in the shallow Mahogany ne and has utilized only the room and pillar mining method. The U.S. Bureau of Mines is anning a demonstration mine in the deep, thick oil shale deposits in Colorado. This paper scribes the four mining concepts that are planned for demonstration and the interlationship of these concepts and the environment. The environmental aspects of oil shale velopment are also discussed.

7. Rattien, S., and D. Eaton.
1976. Review of technological, economic, environmental, and institutional issues. In Annu. Rev. of Energy. p. 183-212. Jack M. Hollander, ed. Annual Reviews, Inc., Palo Alto, Calif.

chnological, economic, environmental, and institutional issues relating to the development f a commercial oil shale industry are reviewed. It is concluded that a commercial shale oil dustry is feasible from a resource and technology perspective. Although there are unanswered estions about water supplies and the environmental impact of a developing shale oil industry, e chief uncertainty is economic. The outlook for prompt and sizable production of shale oil s uncertain in the absence of Federal intervention.

8. Reck, R. O.
1971. The regional economic and environmental impacts of the uranium mining and milling industry. Ph.D. diss. Univ. Maryland, Baltimore. 204 p. [Diss. Abst. Int. 36/06-A:2891.]

9. Reed, A. K.
1976. Assessment of environmental aspects of uranium mining and milling, final report. 59 p. Battelle Columbus Labs, Ohio. [Available NTIS as PB-266-413-4GA.]

This research program was initiated with the basic objective of making a preliminary assessmen of the potential environmental impacts associated with the mining and milling of domestic uranium ores. All forms of pollution except radiation were considered. The program included a review of the characteristics and locations of domestic uranium ore reserves and a review of the conventional methods for mining and milling these ores. Potential environmental impacts associated with the entire cycle from exploration and mining to recovery and production of yellowcake are identified and discussed. Land reclamation aspects are also discussed. The methods currently used for production of yellowcake were divided into four categories: open pit mining-acid leach process, underground mining-acid leach process, underground mining-alkaline leach process, and in-situ mining. These are discussed from the standpoint of typica active mills that were visited during the program. Flowsheets showing specific environmental impacts for each category are provided.

740. Roels, O. A.
1974. Environmental impact of deep ocean mining. Mining Congr. J. 60(8):34-37.

Discovery of extensive deposits of manganese nodules on the deep ocean floor in many areas of the world's oceans has led to serious studies of the technical and economic feasibility of mining these nodules to extract copper, cobalt, and nickel. The most likely environmental effects of mining manganese nodules are: destruction of the benthic organisms and their habitats in the path of the mining operation; stirring up of sedimentary material as the mining implement sweeps the ocean floor; and introduction of sedimentary material, associated bottom organisms, and bottom water into various layers of the water column, including in some cases, surface water. From a 3-year study of those and related effects it appears that the environmental impact of deep-sea mining will probably be small, provided adequate precautions are taken during the mining operation. Our information to date is incomplete, however; a time series approach is required to establish the condition of the mining site before, during, and after the mining operations to document the change induced by mining and its reversibility.

741. Roels, O. A., A. F. Amos, O. R. Anderson, and others.
1973. The environmental impact of deep-sea mining. 186 p. Natl. Oceanic and Atmosphe Admin., Boulder, Colo. [Available NTIS as COM-74-50 489/5.]

The report gives a literature review of the known physical, chemical, and biological propertie of the sea floor and the water column in the areas of the Pacific Ocean where manganese-nodule deposits of interest to the mining industry occur. The report contains the results of a baseline study of the physical, chemical, and biological characteristics of a manganese-nodule province on the Bermuda Rise in the Atlantic Ocean and of a potentially valuable manganese-nodule mining area in the eastern equatorial Pacific. The results of monitoring of a continuo line bucket dredge manganese-nodule mining test in the Pacific Ocean are also reported. A detailed plan of work for a 3-year period to ensure the environmental safety of deep-sea mining is outlined.

742. Roels, O. A.
1974. Environmental impact of manganese nodule mining. Colloq. Int. Sur. l'Exploit des Oceans, 2nd, Proc., Prepr. and Pap., Paris, France. Oct. 1-4, 1974. 7 p.

The processing and extractive metallurgy of manganese nodules at sea, and the discharge of waste materials resulting from this processing, could be far more dangerous unless adequate precautions are taken. To ensure the safe development of this resource, and to avoid costly and drawn out legal wrangling based on the unsubstantiated opinions of "experts" for opposite viewpoints, it is clearly necessary that an orderly procedure be followed and that all environmental factors related to deep-sea mining be well documented.

743. Ross, D.
1975. Overview: environmental baseline monitoring program, tracts U-A and U-B. Colo. Sch. Mines Quar. 70(4):239-244.

744. Ruedisili, L. C., and M. W. Firebaugh, eds.
1975. Perspectives on energy. 527 p. Oxford Univ. Press, London.

5. Shaine, B. A.
1977. Assessment of environmental penalties introduced by transportation access to Alaska mineral resources. In Vol. II: working papers, analysis of laws governing access across federal lands. Appendix "C", 11 p. Off. Tech. Assessment, Washington, D.C.

e conclusions of the Wilderness Society were that (1) public decision on providing transporta-
on to interior and remote areas of Alaska should consider all the costs and benefits, (2)
ansportation system should not subsidize any commercial venture, (3) routes should be care-
lly studied and planned especially in regard to wildlife.

6. Shilling, R. W., and E. R. May.
1977. Case study of environmental impact: Flambeau Project. Mining Congr. J. 63(1):39-44.

ter 15 years of exploration in northern Wisconsin, Bear Creek Mining Company, the exploration
m of Kennecott Copper Corporation, discovered in 1968 a medium-sized copper-rich massive
lfide ore body, now referred to as the Flambeau deposit. Production, under Flambeau Mining
rporation (FMC), a wholly owned subsidiary of Kennecott, was planned for the mid-1970's.
w a startup date is set for the close of this decade, following the preparation of a State-
quired environmental impact statement by the company, which is described here.

7. States, J. B.
1975. Quantitative baseline definition for terrestrial ecosystems at oil shale tract C-A. In Environmental Oil Shale Symposium Proc. [Oct. 9-10]. p. 135-141. J. H. Gary, ed. Colo. Sch. Mines, Quar. 70(4). 244 p.

8. States, J. B., and others.
1978. A systems approach to ecological baseline studies. 400 p. Ecology Consultants, Inc., Fort Collins, Colo.

9. Stoddart, D. R., C. W. Benson, and J. F. Peake.
1970. Ecological change and effects of phosphate mining on Assumption Island. Natl. Res. Counc., Pac. Sci. Board, Atoll Res. Bull. 136:121-145.

0. Synthetic Fuels.
1975. Review of current developments in oil shale technology, including geological, environmental, and processing reports and patents. Syn. Fuels 12(1):2.1-2.68.

1. Technological Review.
1974. Oil shale and the energy crisis. Technol. Rev. 76:3.

description is given of the oil shale deposits in the Green River formation in the United
ates with information on quantities of oil in place and analyses of the shale and its organic
tter. Various techniques of recovering the crude oil are described and illustrated and
fining methods discussed; the environmental impact of the industry and the economics are
amined. A 100,000 barrel per day plant may cost $300 to $500 million, but the investment
y become attractive when the price of crude reaches $4 per barrel.

2. Tibbs, N. H.
1977. In situ leaching of uranium. In Proc., Third Annual UMR-MEC Conf. on Energy: Energy crisis, an evaluation of our resource potential. J. D. Morgan, ed. Western Periodicals Co., North Hollywood, Calif.

-situ leaching is a relatively new production method for uranium with several advantages.
will contribute an increasing portion of uranium supply as production turns to deposits
accessible to conventional mining methods.

753. Tibbs, N. H., D. L. Rath, and T. K. Donovan.
1978. Environmental effects of uranium exploration and mining. p. 71-78. Proc. of the Fourth Annu. UMR-DNR Conf. on Energy [Univ. Mo., Rolla, Oct. 11-13, 1977]. p. 71-78. Univ. Mo.-Rolla, Dep. Nat. Resour., Exten. Div.

An examination of current practices and suggestions for future operations are presented. The probable cost to the environment of uranium exploration and mining is compared to the environmental costs from other energy sources.

754. USDA Forest Service.
1978. Environmental statement; Diamond Creek Planning Unit, Caribou National Forest. USDA For. Serv., Intermt. Reg., Rep. (Adm) R4-75-15, 370 p. Ogden, Utah.

This report is a complete final environmental impact statement for the Diamond Creek Planning Unit and for lease applications and phosphate prospecting permit applications within that unit. It was prepared by the Forest Service in accordance with Section 102(2) (C) of Public Law 91-190.

755. USDA Forest Service.
1972. A mineral exploration proposal in the Mazatzal Wilderness. Tonto National Forest - Environmental Impact Statement. 47 p. USDA For. Serv., Southwest. Reg., Albuquerque, N.Mex. [Available NTIS as EIS-AZ-72-5355-D.]

The Forest Service has prepared a draft environmental statement for a mineral exploration proposal in the Mazatzal Wilderness. The environmental statement considers probable environme effects or impacts of a proposal for mineral exploration in the Mazatzal Wilderness.

756. USDA Forest Service.
1972. Palzo Restoration Project. Vienna Ranger District, Shawnee National Forest, Williamson County, Ill., E.I.S. 77 p. USDA For. Serv., East. Reg., Milwaukee, Wis. [Available NTIS as PB-207 061-D.]

The proposed project will attempt to utilize treated municipal waste to reclaim abandoned strip-mined land that is presently causing severe water pollution problems. Counties affected in Illinois include Williamson, Saline, and Gallatin. Adverse environmental effects that cannot be avoided may include slight increases in concentrations of cadmium, chromium, nickel, and nitrates in the runoff.

757. U.S. Department of the Interior.
1973. Final environmental statement for the prototype oil shale leasing program, vol. I. Regional impacts of oil shale development. 446 p. U.S. Dep. Interior, Washingt D.C.

758. U.S. Department of the Interior.
1973. Final environmental statement for the prototype oil shale leasing program, vol. III. Description of selected and potential environmental impacts. 697 p. U.S. Dep. Interior, Washington, D.C.

759. U.S. Department of the Interior.
1971. Prototype oil shale leasing program for the States of Colorado, Utah and Wyoming [Specific States are in closing Impact Statement.] U.S. Dep. Interior, Washington, D.C. [Available NTIS as PB-203-318F.]

Effects of oil shale resource development on land and water use, wildlife of area.

760. U.S. Department of the Interior.
1967. Surface mining and our environment. A special report to the Nation. 124 p. U.S. Dep. Interior, Washington, D.C.

61. U.S. Department of the Interior.
1976. Navajo-Exxon uranium development: draft environmental impact statement. Planning Support Group, U.S. Dep. Interior, Bur. Indian Affairs, Billings, Mont.

62. U.S. Department of the Interior.
1977. Draft environmental impact statement. Vekol Hills Project, Papago Indian Reservation, Pinal County, Arizona. 200 p. U.S. Dep. Interior, Bur. Indian Affairs, Phoenix, Ariz.

63. U.S. Department of the Interior.
1971. Preference right phosphate lease application within the Los Padres National Forest, Ventura County, Calif. 39 p. Environ. Impact Statement. U.S. Dep. Interior, Bur. Land Manage., Washington, D.C. [Available NTIS as PB-200-775-D.]

he proposed action under consideration is the issuance of a preference right lease covering ,434 acres that would authorize the U.S. Gypsum Company to extract phosphate ore by the open-it method and produce phosphate compounds and other marketable byproducts on site. The hosphate deposit lies about half-way up the slope between Sespe Creek and the crest of Pine ountain ridge. The phosphate rich zone is known to lie near ground surface in a more or less ontinuous band, varying from 1,000 to 2,000 feet in width. That roughly parallels the ridge f Pine Mountain for a distance of about 5 miles. The company proposes that a two-lane, lack-topped entrance road, capable of handling 25-ton trucks would be built up Chorro Grande anyon to the mine and processing plant. The company proposes to strip off the overburden waste rock) and mine the ore by open-pit methods. A processing plant would be built adjacent o the mine site. A total of 1,152,000 gallons of water per 24-hour period would be drawn rom a well approximately 940 ft deep. Considerable electric power will be needed. This ould be supplied either from local power lines or from diesel or natural-gas powered generators n site. A transmission line 14 miles long would be needed to use existing power. Currently here are an estimated 60 to 70 California condors in existence and this bird is on the list f endangered species. The Los Padres National Forest is the hub of their range, containing ll currently known nesting sites and having considerable importance as a wintering area. One esting site will definitely be affected. There will be increased erosion and resulting iltation caused by disturbance to the landscape. Gases and particulates are potential sources f air pollution. Noise might also be a problem.

64. U.S. Department of the Interior.
1977. Proposed alunite project: final environmental statement. 579 p. U.S. Dep. Interior, Bur. Land Manage., Washington, D.C.

65. U.S. Department of the Interior.
1973. Proposed phosphate leasing on the Osceola National Forest in Florida, E.I.S. 533 p. U.S. Dep. Interior, Bur. Land Manage., Silver Springs, Md. [Available NTIS as EIS-FL-73-1923-D.]

he action under consideration is the issuance of 41 phosphate preference right leases for 2,000 acres on the Osceola National Forest, north central Florida. Issuance of these leases ould result in surface mining approximately 30,000 acres of the forest. This mining would esult in the permanent removal of 120,000,000 tons of phosphate rock over a period of approxi-ately 30 years. Approximately six endangered species would have their habitat temporarily or ermanently removed. Approximately 9,000 acres of the forest would be converted to lakes and onds.

66. U.S. Department of the Interior.
1971. Proposed oil shale retort research project, Anvil Points, Colorado. U.S. Dep. Interior, Denver, Colo. [Available NTIS as PB-200-436-D.]

67. U.S. Department of the Interior.
1976. Development of phosphate resources in southeastern Idaho: final environmental impact statement. 1253 p. U.S. Dep. Interior, Geol. Surv. (Lead Bur.), Bur. Land Manage., and USDA Forest Service.

768. U.S. Environmental Protection Agency.
1973. Environmental analysis of the uranium fuel cycle. Part I - fuel supply. U.S. Environ. Protec. Agency, Off. Radiation Prog., EPA-520/9-73-003-B, 151 p.

769. U.S. Environmental Protection Agency.
1973. Environmental evaluation of Mines Development, Inc., uranium and vanadium milling operations at Edgemont, South Dakota. U.S. Environ. Protec. Agency, Region VIII, SA/TSB-18, 55 p.

770. U.S. Environmental Protection Agency.
1976. Environmental analysis of the uranium fuel cycle - part IV. U.S. Environ. Protect. Agency, Rep. EPA 520/4-76-017, 16 p. Washington, D.C.

771. Van Tassel, A. J., ed.
1975. The environmental price of energy. 326 p. Lexington Books, D. C. Heath and Company, Lexington, Mass.

772. Walker, E. B.
1971. Energy and environment. In Western Resources Conf. Proc. [Golden, Colo., July 6-8]. p. 87-97. Colo. Sch. Mines, Golden. 275 p.

773. Weaver, G. D.
1973. Environmental hazards of oil-shale development. Ph.D. diss. Johns Hopkins Univ., Baltimore, Md. [Univ. Microfilms, order No. 76-11,235.]

Oil-shale deposits of the Green River formation underlie about 17,000 square miles of land in northwestern Colorado, northeastern Utah, and southwestern Wyoming. A prototype development program for the federally owned lands, which comprise about 72 percent of the total acreage, was announced in June 1971. Commercial development within the near future would necessarily involve mining and surface retorting of the oil-shale rock. A minimum sized plant using underground mining would remove support from beneath 3,000 acres over a 20-year life. The land disturbed by open-pit mining and solid waste disposal could exceed 7,000 acres over a 20-year life. Consumptive water use by industrial processing and related urban needs is expected to range upward to 124,400 acre-feet per year in 1985 and would increase the projected salinity concentration at Hoover Dam by 6 to 10 mg/l. Associated penalty costs to the regional economy, excluding Mexico, would total as much as $800,000 annually. Atmospheric emissions would produce serious air pollution unless the industry exercises careful judgment in the choice of fuels, the removal of stack gases and particulates, and the siting of emission sources. Release from valley sources could produce extraordinarily high ambient concentrations because of the persistent nocturnal inversions that characterize the region.

774. Weir, D. N.
1977. Interaction of placer mining and natural ecosystems in southeast Alaska. In Papers presented at the Second Annual Convention, Alaska Miners Assoc., Anchorage. p. 6-7. Alaska Miners Association, Anchorage.

Plant and animal community studies have been conducted along the Tuluksak River in southwest Alaska since 1962. Placer gold was mined in the area continuously since 1908. The effects of the mining on the natural ecosystem have been studied. The mining disrupts the climax of the forest and allows for secondary succession to commence with the invasion of broad-leafed species such as willows. Bird populations reflect this community diversity. Song birds and predatory birds are diverse with stable numbers.

775. Western Energy and Land Use Team.
1978. Project status reports: a summary. 67 p. U.S. Fish and Wildlife Serv., Biol. Serv. Prog., Fort Collins, Colo.

This report presents updated project summaries of the Western Energy and Land Use Team (WELUT). Projects are organized within four study categories. The categories are: decision processes and information needs; ecological concepts information and rapid assessment techniques; valuati of wildlife; and revegetation, reclamation, restoration, and mitigation.

76. Wildung, R. E., and others.
1977. Terrestrial effects of oil shale development. In Pacific Northwest annual report for 1976 to the ERDA Assistant Administrator for Environment and Safety. p. 2.1-2.8. B. E. Vaughan, ed. Battelle Pacific Northwest Labs, Richland, Wash. 243 p. [Available NTIS as BNWL-2100 (Pt. 2).]

77. Wixson, B. G.
1975. RANN (Research Applied to National Needs) utilization experience. Case study No. 2. Environmental pollution in the New Lead Belt. 25 p. Research Triangle Inst., Research Triangle Park, N.C. [Available NTIS as PB-247 246/2ST.]

he rapid development of the lead mining industry in the "New Lead Belt" of southeastern
issouri caused serious concern as to the effects of lead mining activities on the surrounding
irgin forest ecosystem. The objectives of this research are to examine the extent and causes
nd effects of heavy metal contamination from lead mining and smelting on the surrounding
orest, and to develop information for State and Federal agencies so that appropriate corrective
ction could be taken. This project is a good example of a well-utilized research program
aving significant value to industry, government, and to the public and regulatory agencies in
cooperative effort to understand and solve a potentially serious problem.

78. Wixson, B. G., E. Bolter, N. L. Gale, and others.
1972. The lead industry as a source of trace metals in the environment. 22 p. Paper presented at the Environmental Resources Conference on Cycling and Control of Metals [Batelle Memorial Institute, Columbus, Ohio, Nov. 1972.]

ining, milling, transportation,and smelting of lead ore in the Viburnum Trend area of south-
astern Missouri are discussed with emphasis placed on pollution introduced into the environment
uring each of these processes. During the mining and milling processes it is possible for
ead and other trace metals to enter the environment from mine water, from dust particles
esulting from the grinding process, and from the tailing dams at settling ponds. Lead concentra-
ions exceeded 0.1 ppm 42 times during a year-long survey of stream water. The benthic flora
ssociated with nutrient trapping and recycling were seen as excellent filters for ore particles.
long transportation routes elevated levels of trace elements were found up to 100 ft from the
oadway. Open trucks and railroad cars contribute to wind-blown trace metals in the environment.
melting operations introduce lead, zinc, copper, and cadmium particulate matter into the air.
reas around smelting plants were monitored and fallout decreased with increased distance from
he stack.

79. Wixson, B. G., E. Bolter, N. L. Gale, and others.
1977. The Missouri lead study: an interdisciplinary investigation of environmental pollution by lead and other heavy metals from industrial development in the New Lead Belt of southeastern Missouri, vol. I. Research applied to national needs. 566 p. Univ. Missouri, Rolla. [Available NTIS as PB-274 242/7ST.]

n interdisciplinary research team has studied trace contaminants associated with the production
f lead for the past 7 years. The study areas are described along with a history of lead
ining in Missouri, geology, mine and milling procedures, and lead smelting operations. The
'New Lead Belt" is contrasted with century-old mining problems encountered in the "Old Lead
elt" district. Economic benefits are discussed regarding national and international mineral
mpacts. Research has determined the background values, established natural baselines, and
valuated the lead mining and smelting industry. Sources of trace metals in the environment
ere found to be associated with the mining-milling operations, transporting ores, and the
melter-refinery process. Information storage and retrieval systems are documented for sample
andling. Analytical procedures for studying lead levels in deer bone are presented along
ith a summary of findings. Volume I focuses on air quality, soils and geochemical studies,
ater quality studies, and water quality-biological aspects.

780. Wixson, B. G., E. Bolter, N. L. Gale, and others.
1977. The Missouri lead study: an interdisciplinary investigation of environmental pollution by lead and other heavy metals from industrial development in the New Lead Belt of southeastern Missouri, vol. II. Applied science and research applications. 562 p. Univ. Missouri, Rolla. [Available NTIS as PB-281 859/9ST.]

An interdisciplinary research team has studied trace contaminants associated with the productio of lead for the past 7 years. The study areas described along with a history of lead mining in Missouri, geology, mine and milling procedures, and lead smelting operations. The "New Lead Belt" is contrasted with century-old mining problems encountered in the "Old Lead Belt" distric Economic benefits are discussed regarding national and international mineral impacts. Research has determined the background values, established natural baselines, and evaluated the lead mining and smelting industry. Sources of trace metals in the environment were found to be associated with the mining-milling operations, transporting ores, and the smelter-refinery process. Information storage and retrieval systems are documented for sample handling. Analytical procedures for studying lead levels in deer bone are presented along with a summary of findings. Other advanced analytical studies are described for thallium and the use of *Drosphila* (fruit flies) as an environmental monitor. Volume II focuses on accumulation of toxic heavy metals by vegetation and remote sensing data analysis and computer aided sampling.

N. Miscellaneous Citations

Section N contains a variety of citations, some from popular journals and some written r the nonscientific community.

81. Bishop, J., Jr.
1974. Oil shale: bonanza or bust for the Rockies? Natl. Wildl. 12(3):11.

82. Business Week.
1971. Cutting Florida's strip mining ills. Business Week 2157:43.

83. Business Week.
1973. An open-pit dilemma for Butte, Montana. Business Week 2308:92,94.

84. Caudill, H. M.
1973. Protecting our environment: farming versus strip mining. Current (156): 37-45.

85. Chaney, E.
1977. Phosphate fate will determine Idaho high country's fate. Audubon 79(2): 123-126.

86. Engineering and Mining Journal.
1973. Cominco collects 1970's dividend from 1920's pollution control effort. Eng. and Mine J. 174(9):121-124.

87. Evans, K. A., E. W. Uhleman, and P. A. Eky.
1978. Atlas of western surface-mined lands: coal, uranium, and phosphate. 394 p. Western Energy and Land Use Team, Off. Biol. Serv., U.S. Fish and Wildlife Serv., Fort Collins, Colo.

88. Goldstein, J.
1975. "New" fertilizers vs. strip mining. Organic Garden. and Farm. 22(6):98-99.

89. Johnson, C., and J. Gropper.
1976. Sand and gravel operations: conflicts and choices. Utah Sci. 37(1):14-19.

90. Li, T. M.
1975. Environmental compliance assures future production at Jaquays asbestos operation. Mining Eng. 27(3):40-45.

91. Line, L., ed.
1973. What we save now: an Audubon primer of defense. 438 p. Natl. Audubon Soc.

92. Loucks, R. A.
1977. Occidental vertical modified in situ process for the recovery of oil from oil shale: phase I. Occidental Oil Shale, Inc., Grand Junction, Colo.

ince early 1973, Occidental Oil Shale, Inc. (OXY) has processed three small-scale modified in itu retorts (retorts 1E, 2E, and 3E) in its research mine, and is currently processing the econd large-sized retort (retort 5) in its development mine; both mines are located on OXY's .A. shale property northeast of De Beque, Colo. Progress of the project since November 1, 976, is summarized starting with the preblast activities and the startup for retort 5, through he mining progress in the formation of retort 6. The environmental aspects including the equired permits are discussed along with the geology and hydrology data from the C-B tract. esults of various studies on potential markets for shale oil are presented and the schedules resented in OXY's proposal to ERDA are compared with the schedules achieved through October 977. A section is included on future plans.

93. Mamen, C.
1973. Island copper: ecology wise. Can. Mining J. 94(7):31-33.

794. Soucie, G.
1973. Oil shale: details of Interior's prototype program emerge from 3,200-page report. Audubon 75(6):125-127.

795. Soucie, G.
1973. Oil shale: Pandora's new box. In What we save now: an Audubon primer of defense. p. 319-328. L. Line, ed. Natl. Audubon Soc. 438 p.

796. Sumner, D., and C. Johnson.
1974. The great shale robbery. Sierra Club Bull. 59(3):11-14,16.

797. World Mining.
1970. Miners and conservationists discuss ecology in the arid environment. World Mining 6(6):28-29.

APPENDIX I

CROSS-REFERENCE INDEX
OF ENVIRONMENTAL EFFECTS

Subject	Citations describing problems	Citations describing solutions	Other citations	Remarks
AIR RELATED EFFECTS				
Mass emissions	273,274	259		
Fine particles	267,532			
General air quality	262,263,270	254,260,264		Monitoring
Specific:				
Asbestos	252,266,269	256	255	
Sulfur dioxide	275			
Silver	258			
Uranium	243			
Barium	245			
Boron	246			
Copper	247			
Cadmium	250			
Iron mine	272	272		
Lead	244			
Nickel	251,271			
Manganese	268			
Molybdenum	257			
Selenium	248			
Vanadium	253			
Zinc	249			
Respirable dust		261,265		
FAUNA RELATED EFFECTS				
Arthropod	517			
Fish	515		505,506,507,513	
Wildlife, general	112,113,498,512		505,506,507,513	
Wildlife habitat	515	499,502,503,510	509,510,513	
Small mammals	511		101	
Grazing (domestic)	500,501			
Endangered species			509	
Birds	103,108,144			
FLORA RELATED EFFECTS				
Accumulation of heavy metals	482,485,486,488 489,490,491,493 495,496,601		487	
Negative responses to pollution	140,254,260,264 483,496,641,650		61	Lichen
Ecology:				
Population dynamics			484	
Reproductive biology			5,120,121,131 492,508,570	

Subject	Citations describing problems	Citations describing solutions	Other citations	Remarks
cology: (con.)				
Plant succession			110,111,566,584	
Species adaptability and usefulness in revegetation		671	126,127,171,568 571,577,581,604 613,615,618,619 620,266,650	
Mycorrhiza		143,157		
ENERAL ENVIRONMENTAL IMPACT				
entonite	723			
lay	698			
oal			62,86	
opper	704,746	215,227		
nergy/fuels	675,676,681,690 691,696,771,772 735		744	
ead	777,778,779,780			
ignite	706,707			
etals	726			
inerals	697,712,722,725 755		745	
olybdenum	679			
cean mining (manganese)	298,709,713,740 741,742		32	
il shale	221,682,683,684 685,687,689,705 707,717,736,750 757-759,766,773 776	200,219,680	36,711,747,750	
hosphate	716,717,749,763 765,767	217		
and and gravel	688,222,734	199,204,210,213 220,224,225,185		
trip mining	686,692,760			
ar sands	695			
ranium	145,674,693,708 714,724,728,729 730,731,738,739 753,761		678,71,59	

Subject	Citations describing problems	Citations describing solutions	Other citations	Remarks
GENERAL ENVIRONMENTAL IMPACT (con.)				
Zinc	677			
HEALTH				
General			31	
Uranium	519,522,525,527 528,530	520	59	
Radioactivity, radon gas, etc.	521,522,523,524	524		
Metal miners	115			
MISCELLANEOUS				
Data bases			1-94,699-702 710,720,747 748,775	
Environmental measurement			105	
Archaeology	535			
Noise	537			
Trace minerals	532			
Recreation		220,225,232		
REVEGETATION AND RECLAMATION				
Acidic sites	588	123,576		
Aluminum		610		
Arid-West	636	560,636	11,12,15,18,27 35,52,53,55,75 85,93	
Bentonite	154	99,100,104,157 158,191	566	Research
Barrow pits		544		
Coal	632	123,644	6,17,56,92	
Copper	564	126,127,183,562 563,565,602,603 604,629,639,649 659		

Subject	Citations describing problems	Citations describing solutions	Other citations	Remarks
EVEGETATION AND RECLAMATION (con.)				
oastal estuaries, marsh		600,626	12	
rastically disturbed areas		190	16,40,41,48,65,76 91,540	
olomite, limestone		181		
luorspar		585,586,587		
old		591		
ron		611,648,649		
aolin clay		606,607,608		
ead-zinc		599,637,638,667		
anganese		573		
olybdenum		546		
ill tailings		117,118,567	235,239,240	
ine water impoundment		543		
il shale	160	98,128,555,558 579,655,664		
hosphate		123,173,572,574 582,623,640,666		
urface mines		96,153,180,562 635	1,4,9,11,25,26,43 45,47,63,77,78,79 80,81	
and and gravel	650	589,624,627	653	
ar sands		654		
undra	159,588,593,614	109,159,305,546 547,548,549,550 551,552,553,554 557,616,617,618 672	13,72	
ranium	161,596	592,609,625,643	660	
evegetation potential		561,598,628	597	
eclamation planning			30,46,51,630	
conomic aspects			10,236,237,242	

Subject	Citations describing problems	Citations describing solutions	Other citations	Remarks
REVEGETATION AND RECLAMATION (con.)				
Machinery for reclamation			119,163,545	
Techniques for reclamation			172,542,582,593 605,612,628,634 646,656,659,671	
Guidelines, guide books, reference books			216,223,597,642 645,656,657,662 663	
Erosion control			2	
SOLID WASTE				
Management/disposal	398,443,465,476	398,410,437,440	409,470,475	Research ne
Use of	401	396,406,407,433,451	14,408	
SPOILS AND TAILINGS				
Tailings, general	186,402	480	57	Weathering
Tailings, dams and ponds	479	431,479	474	
Tailings, stability	442	137,415	33	
Tailings, specific:				
Aluminum		610		
Asbestos		621		
Bauxite muds	460	460		
Bentonite	106	99,100,104,157 158,191		
Copper	139,448,466,564	126,127,183,461 562,563,565,602 603	604,639,649,659	
Fluorspar		585,586,587		
Gold		591		
Iron ore		611,648,649		
Kaolin clay	453	606,608,609		
Lead	441	637,638,667		
Limestone		435		
Manganese		573		
Oil shale	462,472	98,128,437,558,579 655,664		
Phosphate slimes and tailings	405,442,444,446 473	122,395,403,454 471,574,582,640 666		
Tar sands	444	453	654	

Subject	Citations describing problems	Citations describing solutions	Other citations	Remarks
ailings specific: (con.)				
Uranium	129,135,140,196 412,414,417-428	129,397,400,439 592,609,625,643 660		
Zinc		416		
oil chemistry, general	170,402,448,453			
Saline and sodic		164	89	
Heavy metals	399			
reatments, general		457,458		
Amendments		146,151,165,177		
Mulch		167,169,176		
icroorganisms	139,182	184,394,467 560		
ATER RELATED EFFECTS				
eneral water quality	107,287,312,330 386,694	276	88	Navigable waters
eochemical	281,293,294,343			
pecific water quality:				
Asbestos	309			
Bentonite	376			
Copper	295,371,380			
Gold	296	296		
Heavy metals	142,278,280,320 391		66	Mobilization
Hazardous	130,288,306,316 326			
Limestone		317		
Lead-zinc	295,280,304,333 370,371	374,328,375,392		
Mercury	296	296		
Molybdenum	296	296		
Phosphate	277,306,311,313 316,326,387,388	277		
Placer mine	192,285	291		
Oil shale	283,334,336,338 339			
Silver	296	296		
Tar sands	384			
Thallium	310,393			
Tungsten	296	296		

Subject	Citations describing problems	Citations describing solutions	Other citations	Remarks
Specific water quality: (con.)				
Uranium	130,288,307,308 314,315,321,322 323,324,325,327 332,342,377	708		
Effluent	290,312	279	289,303	Guidelines o limitation
Acid mine drainage	124,352,358,364	178,347-369 (except 352,358 364)	4,10,49,60	
Hydrology	311,335,338	305	534	
Erosion	179	2		
Stream channel	344	136		
Ground water	155,189,308,313 318,325,338	148,300		
Water requirement (consumptive use)	301,319,331,334 345	148,300	7	Management
Water resources	297		8	
Abandoned mine effluent	331,333,336,455	178,331		

APPENDIX II

NATIONAL TRENDS
MATRIX SUMMARY INDEX

Impacts	Commodities												
	COMMODITIES	COASTAL PLAINS -eastern phosphates	-gypsum	CLAYS & BAUXITE -clays	-bauxite	OPEN PIT (DRY) -copper	-molybdenum	-western phosphate	OPEN PIT (WET) -iron	-other	-copper/nickel	-placer mining	OIL SHALE/TAR SAND -oil shale
I. AIR POLLUTION									272	268	271		
A. Fugitive dust						261 265	261 265		261 265 266	261 265 639			
B. Toxic emissions (asbestos, radon)							257		252 262		251 256		
II. SURFACE WATER POLLUTION						*295	* 296					285	179 189
A. Chemical													
1) sedimentation												291	
2) radio-activity		316 326						316 326					
3) process effluent		277							290 303		303		
4) heavy metals						142 C21			C21		C21		
5) salinity-buildup and asbestos													283
6) acid mine drainage	- - - - - - See section IIIF, citations 347-369, and 4,10,49,60 - - - - -				*	*					*		
B. Physical													
1) Stream channel quarry ponds												H5	
2) consumptive use		300											7
3) water management		346 300 138 302											301 334 336 319

Commodities												
-tar sands	SAND & GRAVEL -sand & gravel	-crushed stone	-limestone	UNDERGROUND -sulfides	-solution mining	-exploration	NATURAL BUILDING STONE	DISCONTINUOUS ORE BODIES -vanadium	-uranium	-bentonite	GENERAL CITATIONS	REMARKS
270 275											273,G1,G3[1]	
	261 265	261 265		261 265			261 265				261,265,267 *415,G2,G4 G6	*Dust abatement
				244 250				253	*243		274	*See "Human Health," p. 132
386			*317	*295 *297 *328 333					*327	107 134	*331,333 336,F19	*Water pollution control methods
									C7		2,C2,C3,C11 C22	
									287,288 324,332 315,321 322,323 F12,F22			
				303 312,343 344				303	303 342			
				278 280,281, 320							66,310 F11,F20	
385											309	
- - -	- - -	- - -	- - -	*178	- - -	- - -	- - -	- - -	- - -	- - -	124,125,8A	*Commodities with acid drainage problems
	F9,F10 F13,H8											
											F15,F16,F17	

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[1] Citations with a letter preceding the numeral refer to comments in Section I.

Impacts	COMMODITIES	COASTAL PLAINS -eastern phosphates	-gypsum	CLAYS & BAUXITE -clays	-bauxite	OPEN PIT (DRY) -copper	-molybdenum	-western phosphate	OPEN PIT (WET) -iron	-other	-copper/nickel	-placer mining	OIL SHALE/TAR SAND -oil shale
C. Biological		388 505			380	381 383		387	393	371 372		192	175 187 188
1) effects on organisms		506 507											
2) effects on aquatic habitat					380	382 383							
III. GROUND WATER POLLUTION								313					148 338
A. Toxic contaminates		306				294 F4					F4		
B. Hydraulic impacts		311				155							335 339
IV. RADIOACTIVITY													
V. RECLAMATION		74,84 574 582 630 666		607 608 C17		165 183 562 563 603 E12	672	173 574 582 C9	648 649 E11 E21	573 621 E11	562 563 629 635 649		36,64 97,98 128,14 555,64 655
A. Species for revegetation				641		127 581 604	584	123					664
B. Soils and spoils problems		122 405 444 446		453		448 467 564 D6		170 394	611	D6	D6 E19	564	402 462 472 D4
C. Climatic factors and stubborn conditions		473		606	610	565 576 602 B10	546- 554 588 B12						160 558 579

Commodities												
-tar sands	SAND & GRAVEL -sand & gravel	-crushed stone	-limestone	UNDERGROUND -sulfides	-solution mining	-exploration	NATURAL BUILDING STONE	DISCONTINUOUS ORE BODIES -vanadium	-uranium	-bentonite	GENERAL CITATIONS	REMARKS
35 36				370 374,375 378,391					377	376	102,373,379 391,392,393 F21,H3,H5	
	H6 H7 H8									132 133 376	384 C3	See WILDLIFE, "fisheries," next page.
				318							6,F14	
									286,287 307,308 315,F4		309,F18,K13	
									325		F1,F2,F3	
									412 414,418 428,K4 K6,K12		129,145,194 196,K11	See SURFACE WATER POLLUTION, p. 135, and HEALTH, p. 132
1 8 4	589 590 624 627 653	155	180 181	585 586 591 599 637 638	44		C1 C4 C16	161	194 196 592 609 643 E4	146 154 157 176 E4 E20	1-94,96,101 116,117,143 151,153,159 163,167,177 540,543,545 597,601,605 612,633,636 639,640,644 645,650,661 662,663,671	
									625	99 E3 E7	120,121,123 131,171,563 568,570,571 614,615-618 620,622	
44 13 14	646 650			399 467 D7					34,35, D11 D14	106 D1 E16	61,89,169 560,650,D2 D3,D5,D8,D9 D10,D12,D13	
	600			587				596	596 B5 B6 B11 B12	B5 B6 B11	13,14,27,72 109,110,111 542,551,552 557,578,593 614,B1,B2,B3 B4,B7,B8,B9 B13,B14	

	Commodities											
Impacts	COMMODITIES	COASTAL PLAINS -eastern phosphates	-gypsum	CLAYS & BAUXITE -clays	-bauxite	OPEN PIT (DRY) -copper	-molybdenum	-western phosphate	OPEN PIT (WET) -iron	-other	-copper/nickel	-placer mining	OIL SHALE/TAR SAND -oil shale
D. Tailings, slimes and waste(management and disposal)		122 395 403 454 471 572 623 F7	474		460	461		442	451 477 478 481		466 639 659		410 437
E. Effects on plants						126 483			488 496	485	483 488		
VI. WILDLIFE		505 509									635		498 512
A. Effects on organisms		506 507											
B. Alteration of habitat		509											H14
1) fisheries						381 382 393		387				192 H5	
2) wet lands		388										H5	
3) terrestrial													
4) mitigation of negative effects													
C. Threatened or endangered species		509											
VII. CULTURAL IMPACTS													535
VIII. LAND USE (planning and policy)		212 217		208		215 227							200 204 206 207 221

Commodities												
-tar sands	SAND & GRAVEL -sand & gravel	-crushed stone	-limestone	UNDERGROUND -sulfides	-solution mining	-exploration	NATURAL BUILDING STONE	DISCONTINUOUS ORE BODIES -vanadium	-uranium	-bentonite	GENERAL CITATIONS	REMARKS
57		435		416 441 476			435	33	34,35 395 400 429 430 439 660 C18	631	118,396,398 401,406,407 408,409,433 440,443,465 628,C5,C8,C13 C19	
				482 484,486 487,489 495				K12		104 158 191 198	658,K10	
				511						198	475,513,517 595,637,652 H4	
	499 626			392 393						112 113 144	513,H2,H11 H12,*H10	*Migration block
	H6 H7			391				377			390,H3,H5	
	H7 H8									108 132 133 376	66,H4	
										103 144 514	502	
	499										502,503,510 513,H13	
											H9	
											K7	
185 99,201 03,210 13,214 20,222 24,229 33											19,44,51,205 211,212,216 218,223,226 228,231,232	

		Commodities											
Impacts	COMMODITIES	COASTAL PLAINS -eastern phosphates	-gypsum	CLAYS & BAUXITE -clays	-bauxite	OPEN PIT (DRY) -copper	-molybdenum	-western phosphate	OPEN PIT (WET) -iron	-other	-copper/nickel	-placer mining	OIL SHALE/TAR SAND -oil shale
IX. HUMAN HEALTH		521											
X. GENERAL IMPACTS		716 749 765		698		746	679	716 717 763 767					704
XI. OTHER IMPACTS (noise, roads)													
XII. ECONOMIC						236							236 242
XIII. LEGAL		235											

Commodities												
-tar sands	SAND & GRAVEL -sand & gravel	-crushed stone	-limestone	UNDERGROUND -sulfides	-solution mining	-exploration	NATURAL BUILDING STONE	DISCONTINUOUS ORE BODIES -vanadium	-uranium	-bentonite	GENERAL CITATIONS	REMARKS
										35,59 519 520 522 530 K14	31,115	
	*185 *199 *204 *210 *213 *220 222 *224 *225 688 734	222 688 734		677 776- 780					71 145 674 678 693 712 714 724 728- 731 738 739 753 761		536	*Mitigation
	536 537 K3	536					K2 K5					K1,K5
7											9,K8 239,240	

Richardson, Bland Z., and Marilyn Marshall Pratt, compilers.
1980. Environmental effects of surface mining of minerals other than coal: annotated bibliography and summary report. USDA For. Serv. Gen. Tech. Rep. INT-95, 145 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

This bibliography contains annotated references to literature about the environmental effects of surface mining for minerals other than coal. Each reference is indexed by commodity, general subject, and environmental problem. The publication includes a section of references to unpublished, "soft" literature and a summary of professional concerns about mining impacts throughout the United States.

KEYWORDS: bibliography, research, surface mining, reclamation, environmental impacts, social aspects

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The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

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Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Provo, Utah (in cooperation with Brigham Young University)

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NOVEMBER 1981

PHOTO GUIDE FOR APPRAISING DOWNED WOODY FUELS IN MONTANA FORESTS:

Grand Fir–Larch–Douglas-Fir, Western Hemlock, Western Hemlock–Western Redcedar, and Western Redcedar Cover Types

William C. Fischer

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U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
OGDEN, UTAH 84401

THE AUTHOR

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RESEARCH SUMMARY

Four series of color photographs show different levels of downed woody material resulting from natural processes in four forest cover types in Montana. Each photo is supplemented by inventory data describing the size, weight, volume, and condition of the debris pictured. A subjective evaluation of potential fire behavior under an average bad fire weather situation is given.

Instructions are provided for using the photos to describe fuels and to evaluate potential fire hazard.

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Grand Fir–Larch–Douglas-Fir, Western Hemlock, Western Hemlock–Western Redcedar, and Western Redcedar Cover Types

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ACKNOWLEDGMENTS

The fire behavior potential ratings assigned to the photos in this guide are the results of on-site evaluation by the following fire managers and researchers:

Donald E. Abbott, Deerlodge National Forest
George F. Bissonette, Kootenai National Forest
Dr. James K. Brown, Northern Forest Fire Laboratory
Fred L. Cavill, Lolo National Forest
Farrell G. Cooper, Lolo National Forest
Ronald G. Curtiss, Kootenai National Forest
Walter L. De Zell, Bitterroot National Forest
John B. Dillon, Kootenai National Forest
Wyatt W. Frost, Bitterroot National Forest
Horace F. Goodwin, Custer National Forest
Del Goss, Helena National Forest
Patrick F. Hartless, Northern Forest Fire Laboratory
Roger O. Hearst, Lolo National Forest
Jerry A. Hinman, Bitterroot National Forest
Robert Kellogg, Helena National Forest
Douglas H. Mackay, Lewis and Clark National Forest
Jerrald W. Miller, Lolo National Forest
Robert W. Mutch, Lolo National Forest
Dr. Rodney. A. Norum, Northern Forest Fire Laboratory[1]
John V. Puckett, Northern Region Aviation and Fire Management
Delmar L. Radtke, Northern Region Timber Management
Charles E. Rodgers, Lolo National Forest
Everett Stiger, Helena National Forest
Russel H. Trodstad, Lewis and Clark National Forest
Walter J. Tomascak, Custer National Forest
Don V. Williams, Northern Region Aviation and Fire Management (Retired)
Jerry Williams, Montana State Division of Forestry

The author gratefully acknowledges the help received from these men and thanks them for their willingness to share their expertise. Nonan V. Noste, Northern Forest Fire Laboratory, conducted many of the fire behavior potential rating sessions. His help is also gratefully acknowledged.

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[1] Subsequently assigned to Institute of Northern Forestry, Fairbanks, Alaska.

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SERIES 2 - WESTERN HEMLOCK, WESTERN REDCEDAR - WESTERN HEMLOCK, WESTERN REDCEDAR SAF COVER TYPES 224, 227 AND 228 23

This photo guide contains information that can be used to appraise the dead woody debris on the forest floor of grand fir - larch - Douglas-fir, western hemlock, western redcedar - western hemlock, and western redcedar forest cover types (SAF 1954) in Montana. The guide is primarily for natural (nonslash) fuels, although some photos include old logging and thinning slash. Natural fuels result from wind, snow, and mechanical breakage, natural pruning of lower branches, needle fall, windthrow, blowdown, and the falling of trees killed by insects, disease, fire, and competition for light and moisture. The old logging and thinning slash shown has either been treated or left untreated. It can therefore be considered a part of the natural fuel complex.

This guide is designed to help forest managers describe the deadwood on the forest floor, to estimate the amount of such material, and to evaluate its fire hazard. The photos show a variety of fuel situations that exist in grand fir, western hemlock, and western redcedar forests in Montana and surrounding Northern Rocky Mountain areas.

The fuel appraisal obtained from this guide can be used to plan fire management strategies including fire prevention, fuel treatment, prescribed fire, dispatching for fire suppression, and establishing criteria for unscheduled prescribed fires.

The photos provide a relatively quick and inexpensive aid for accomplishing fuel appraisal over large forested areas. Although the precision of this procedure is unknown, it is expected to be intermediate: less than standard fuel inventory but greater than designating a stylized fuel model such as used in the National Fire Danger Rating System.

Perhaps the strongest feature of this series is the fire potential rating with each photo. Alternative methods for evaluating fire potential are generally unavailable, and those methods that do exist are outdated or not well suited for rating nonuniform fuel situations.

USING THE PHOTOS

Arranging the Photos

The photos and accompanying data sheets are presented in two series:

Series 1—Grand fir - larch - Douglas-fir cover type.

Series 2—Western hemlock, western redcedar - western hemlock, and western redcedar cover types.

Within each series, the photos are arranged according to total fuel loading. The first photo in each series shows the lightest fuel load, the last shows the heaviest load.

The Data Sheet

The fuel complex shown in each photo is described on an accompanying data sheet in terms of the following characteristics:

1. Forest cover type.
2. Montana habitat type.
3. Stand and site data: age of overstory dominants, average slope, aspect, elevation, and fire ecology group.
4. Down and dead woody fuel loadings by size class.
5. Other fuel data: average duff depth and for fuels 3 inches (7.62 cm) in diameter and greater, the average diameter, the percent rotten, and the volume of sound material.
6. National Fire Danger Rating System fuel model.
7. Stylized fuel model.

Symbols used for forest vegetation are the standard symbols for Northern Region plants (USDA Forest Service 1969). The symbols represent the first two letters of the generic name and the first two letters of

Describing the Fuel Complex

Several important fuel characteristics can be seen in each photo: (1) The amount of fuel in the different diameter classes, (2) the general condition of the fuel (sound versus rotten), (3) the distribution of the fuel over the area, and (4) the depth of the fuel (each black and white section on the plot marker is 1 foot [0.3048 m]). Consequently, the manager can use the photos to estimate values for these characteristics of woody debris on the forest floor.

To use the photos to describe downed woody fuels, simply inspect the fuel complex and then select the photo that most nearly compares with what is on the ground. Then use the information on the data sheet to describe the observed fuel complex.

Perhaps no one photo adequately represents the actual situation. If this is the case, select two photos that bracket the observed fuel complex and then interpolate between the values on the data sheets accompanying the selected photos.

Rather than trying to select one photo or a pair of photos that best reflects the entire fuel complex, the user could describe each of the above-mentioned fuel characteristics separately. This could be done by using the following procedure suggested by Maxwell and Ward (1976a, 1976b), as adapted by Koski and most nearly matches, or photos that bracket the observed situations.

3. For each characteristic, obtain a value from the data sheet accompanying the selected photo (or interpolate a value if a pair of photos was selected).

The above procedure should only be used when a single photo or a pair of photos can't be used to describe the observed situation. For most fuel situations, any improvement in estimates obtained by rating each fuel characteristic separately is not justified by the increased time it takes to get them.

These procedures refer to use of the photos at a specific point. This can be a representative point and the results applied to an entire forest stand. This method is satisfactory when the fuels are uniform throughout the stands. The photos can be used to sample when nonuniform fuels preclude the selection of a representative point. The procedure is as follows:

1. Establish 10 or more points, spread systematically through the stand.
2. At each point evaluate the fuels within clear eyesight.
3. Summarize the results as a simple average for the stand or express the results as the percent of area in several classes (for example, 40 percent of stand >10 tons/acre, 60 percent of stand <30 tons/acre).

The data sheet for each photo contains adjective ratings for five different expressions of fire behavior: rate of spread, intensity, torching, crowning, and resistance to control. An overall fire behavior potential rating is also given for the fuel complex pictured. The ratings are for an "average bad" fire weather situation defined as: 80°-90° F temperature (27°-32° C), 15-20 percent relative humidity, 10-15 mi/h windspeed (16-24 km/h), and 4 weeks since a significant rain (0.10 inch [0.25 cm] or greater).

This approach to estimating fire potential is not without precedent in the Northern Rocky Mountains. In many ways it is a refinement of the time-tested concept of fuel rating introduced more than 40 years ago by L. G. Hornby (1936).

The adjective ratings nil, low, medium, high, and extreme are defined as follows for each of the different expressions of fire behavior:

Rate of Spread

Nil—fire cannot sustain itself.

Low—spread will be slow and discontinuous.

Medium—uniform spread possible, but can be stopped by aggressive ground attack with hand tools.

High—spread will be rapid; indirect attack on fire front may be required for control.

Extreme—spread will be explosive; little chance of control until weather changes.

Intensity

Nil—fire cannot sustain itself.

Low—cool fire; very little hot spotting required for control.

Medium—fire will burn hot in places; aggressive hot spotting with hand tools likely to be successful.

High—too hot for sustained direct attack with hand tools; aerial tankers or large ground tanker required to cool fire front.

Extreme—direct ground attack not possible; air or ground tanker attack likely to be ineffective.

Torching

Nil—no chance of torching.

Low—occasional tree may torch-out.

Medium—pole-sized understory trees likely to torch-out.

High—Most of understory and occasional overstory trees likely to torch-out.

Extreme—entire stand likely to torch-out.

Crowning

Nil—sustained spread in crowns will not occur.

Low—sustained spread in crowns unlikely.

High—sustained crowning likely.

Extreme—sustained crowning will occur.

Resistance to Control

Nil—no physical impediments to line building and holding.

Low—occasional tough spots but not enough to cause serious line building and holding problems.

Medium—hand line construction will be difficult and slow, but dozers can operate without serious problems.

High—slow work for dozers, very difficult for hand crews; hand line holding will be difficult.

Extreme—neither dozers nor hand crews can effectively build and hold line.

Overall

Nil—fire will not sustain itself.

Low—fire can be easily controlled by several smokechasers with hand tools.

Medium—aggressive crew-sized (6-10 persons) initial attack required for successful control.

High—aggressive crew-sized (25 persons) initial attack with substantial reinforcement required for successful control; 10 percent chance that initial control action will fail.

Extreme—90 percent chance that initial control action will fail.

PHOTO GUIDE DEVELOPMENT

This photo guide was developed using the technique explained by Fischer (1981), which involved the following steps:

1. The fuel complexes photographed were selected to represent the range of fuel situations observed to exist for the cover type in Montana.
2. Sample plots are generally laid out and photographed in accordance with procedures suggested by USDA Forest Service (1975).
3. Fuels were sampled and described using fuel inventory and computational techniques developed by Brown (1974).
4. Habitat types are according to Pfister and others (1977). Cover types are according to SAF (1954).
5. Fire potential ratings are based on subjective evaluation by experienced fire managers using the adjective ratings and definitions in the preceding section of this guide.
6. National Fire Danger Rating fuel model assignment was by the author using definitions provided by Deeming and others (1977). Stylized fuel model assignment was by the author using definitions provided by Albini (1976).

8. Stand and site data were obtained using standard forestry field techniques.

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SERIES 1

GRAND FIR - LARCH - DOUGLAS-FIR

SAF COVER TYPE 213

1
6

Stand No. 16

FOREST COVER TYPE: SAF NO. 213, Grand fir - Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 521, Grand fir/queencup beadlily-queencup beadlily (ABGR/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.9	0.20
0.25-1	1.7	0.38
1-3	2.1	0.47
Subtotal 0-3	4.7	1.05
3-6	3.3	0.74
6-10	6.1	1.37
10-20	2.2	0.49
20+	0	0
SUBTOTAL 3+	11.6	2.60
TOTAL	16.3	3.65

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.6 in

6.60 *cm*

Average diameter, 3+fuels: 5.5 in

13.97 *cm*

Percent rotten, 3+fuels: 38 %

Volume of **sound** 3+fuels: 576 ft³/ac

40.3 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PSME	120 yrs
ABGR	90 yrs

Average slope: 10 %

Aspect: northeast

Elevation: 3120 ft 951 *m*

Remarks: moist grand fir bottom

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: low

Torching: medium

Crowning: low

Resistance to control: low

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Ninemile

Drainage: Mill Cr.

Photo taken: 9/22/76

By. W. C. Fischer

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DATA SHEET

Stand No. 15

FOREST COVER TYPE: SAF NO. 213, Grand fir - Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 521, Grand fir/queencup beadlily-queencup beadlily phase (ABGR/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.6	0.13
0.25-1	1.3	0.29
1-3	3.3	0.74
Subtotal 0-3	5.2	1.16
3-6	3.6	0.81
6-10	3.2	0.72
10-20	8.5	1.91
20+	0	0
SUBTOTAL 3+	15.3	3.44
TOTAL	20.5	4.60

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 3.0 in 7.62 cm

Average diameter, 3+fuels: 5.9 in 14.99 cm

Percent rotten, 3+fuels: 81 %

Volume of **sound** 3+fuels: 230 ft³/ac 16.1 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

ABGR	85 yrs
LAOC	82 yrs

Average slope: 20 %

Aspect: north

Elevation: 3450 ft 1052 m

Remarks: stream-side

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: medium

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Ninemile

Drainage: Mill Cr.

Photo taken: 9/22/76

By. W. C. Fischer

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3

DATA SHEET

Stand No. 63

FOREST COVER TYPE: SAF NO. 213, Grand fir - Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 510, Grand fir/beargrass (ABGR/XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.4	0.09
0.25-1	1.9	0.43
1-3	0.7	0.16
Subtotal 0-3	3.0	0.68
3-6	3.6	0.81
6-10	8.3	1.86
10-20	7.4	1.66
20+	0	0
SUBTOTAL 3+	19.3	4.33
TOTAL	22.3	5.01

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H/G	8/10

OTHER FUEL DATA

Average duff depth: 1.9 in
4.83 cm

Average diameter, 3+fuels: 6.5 in
16.51 cm

Percent rotten, 3+fuels: 31 %

Volume of **sound** 3+fuels: 1069 ft³/ac
74.8 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	125 yrs
ABGR	112 yrs
PICEA	93 yrs
ABLA	80 yrs

Average slope: 20 %
Aspect: northwest
Elevation 4530 ft 1381 m

Remarks:
Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: low
Crowning: low
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Rattlesnake Cr.

Photo taken: 7/13/77
By W. C. Fischer

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DATA SHEET

Stand No. 65

FOREST COVER TYPE: SAF NO. 213, Grand fir - Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 521, Grand fir/queencup beadlily-queencup beadlily phase (ABGR/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.5	0.11
0.25-1	1.9	0.43
1-3	3.6	0.81
Subtotal 0-3	6.0	1.35
3-6	7.2	1.61
6-10	10.8	2.42
10-20	0	0
20+	0	0
SUBTOTAL 3+	18.0	4.03
TOTAL	24.0	5.38

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.6 in, 6.60 cm

Average diameter, 3+fuels: 5.0 in, 12.70 cm

Percent rotten, 3+fuels: 27 %

Volume of **sound** 3+fuels: 1258 ft^3/ac, 88.0 m^3/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO	118 yrs
LAOC	110 yrs
ABGR	90 yrs

Average slope: 32 %
Aspect: southeast
Elevation 4180 ft 1274 m

Remarks

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: high
Torching: high
Crowning: medium
Resistance to control: high

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Rattlesnake Cr.

Photo taken: 7/14/77
By W. C. Fischer

DATA SHEET

Stand No. 67

FOREST COVER TYPE: SAF NO. 213, Grand fir - Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 521, Grand fir/queencup beadlily-queencup beadlily phase (ABGR/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.7	0.16
0.25-1	2.9	0.65
1-3	2.4	0.54
Subtotal 0-3	6.0	1.35
3-6	5.5	1.23
6-10	12.2	2.73
10-20	3.2	0.72
20+	0	0
SUBTOTAL 3+	20.9	4.68
TOTAL	26.9	6.03

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.6 in

6.60 cm

Average diameter, 3+fuels:

5.7 in

14.48 cm

Percent rotten, 3+fuels: 73 %

Volume of **sound** 3+fuels:

452 ft³/ac

31.6 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	156 yrs
LAOC	127 yrs
ABGR	109 yrs

Average slope: 30 %

Aspect: southeast

Elevation 4180 ft 1274 m

Remarks:

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: high

Torching: medium

Crowning: medium

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Rattlesnake Cr.

Photo taken: 7/14/77

By W. C. Fischer

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5

DATA SHEET

Stand No. 25

FOREST COVER TYPE: SAF NO. 213, Grand fir - Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 521, Grand fir/queencup beadlily-queencup beadlily phase (ABGR/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	1.1	0.25
0.25-1	2.2	0.49
1-3	5.5	1.23
Subtotal 0-3	8.8	1.97
3-6	0.6	0.13
6-10	6.3	1.41
10-20	17.1	3.83
20+	2.6	0.58
SUBTOTAL 3+	26.6	5.95
TOTAL	35.4	7.92

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 4.0 in

10.16 *cm*

Average diameter, 3+fuels: 10.0 in

25.40 *cm*

Percent rotten, 3+fuels: 99 %

Volume of **sound** 3+fuels: 16 ft³/ac

1.1 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PICEA	114 yrs
THPL	111 yrs
PSME	110 yrs
ABGR	110 yrs

Average slope: 10 %

Aspect: south

Elevation: 4050 ft 1234 *m*

Remarks: stream-side

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: medium

Torching: low

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Ninemile

Drainage: Stony Cr.

Photo taken: 9/24/76

By: W. C. Fischer

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DATA SHEET

Stand No. 66

FOREST COVER TYPE: SAF NO. 213, Grand fir - Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 521, Grand fir/queencup beadlily-queencup beadlily phase (ABGR/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.6	0.13
0.25-1	1.6	0.36
1-3	1.2	0.27
Subtotal 0-3	3.4	0.76
3-6	3.5	0.78
6-10	4.4	0.99
10-20	26.7	5.90
20+	0	0
SUBTOTAL 3+	34.6	7.67
TOTAL	38.0	8.43

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 4.0 in
10.16 cm

Average diameter, 3+fuels:
7.6 in
19.30 cm

Percent rotten, 3+fuels: 50 %

Volume of **sound** 3+fuels:
1382 ft³/ac
96.7 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	280 yrs
LAOC	256 yrs
PICEA	117 yrs
ABGR	110 yrs

Average slope: 1 %
Aspect: southeast
Elevation: 4180 ft 1274 m

Remarks: stream-side
Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: medium
Torching: low
Crowning: low
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Rattlesnake Cr.

Photo taken: 7/14/77
By: W. C. Fischer

SERIES 2

WESTERN HEMLOCK, WESTERN HEMLOCK - WESTERN REDCEDAR, AND WESTERN REDCEDAR

SAF COVER TYPES 224, 227, AND 228

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DATA SHEET

Stand No. 9A

FOREST COVER TYPE: SAF NO. 227, Western redcedar - Western hemlock

MONTANA HABITAT TYPE: NO. 571, Western hemlock/queencup beadlily-queencup beadlily phase (TSHE/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.4	0.09
0.25-1	1.1	0.25
1-3	0.5	0.11
Subtotal 0-3	2.0	0.45
3-6	1.8	0.40
6-10	4.6	1.03
10-20	0.5	0.11
20+	0	0
SUBTOTAL 3+	6.9	1.54
TOTAL	8.9	1.99

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 2.8 in

7.11 *cm*

Average diameter, 3+fuels: 5.5 in

13.97 *cm*

Percent rotten, 3+fuels: 56 %

Volume of **sound** 3+fuels: 241 ft³/ac

16.86 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

TSHE, THPL	170 yrs
LACO	170 yrs
PIMO	150 yrs
PSME, ABGR	120 yrs

Average slope: 3 %

Aspect: southwest

Elevation: 2950 ft 899 *m*

Remarks. Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Kootenai

Ranger District: Libby

Drainage: Quartz Cr.

Photo taken: 6/27/78

By W. C. Fischer

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DATA SHEET

Stand No. 4A

FOREST COVER TYPE: SAF NO. 227, Western redcedar - Western hemlock

MONTANA HABITAT TYPE: NO. 571, Western hemlock/queencup beadlily-queencup beadlily phase (TSHE/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.6	0.13
0.25-1	1.2	0.27
1-3	1.3	0.29
Subtotal 0-3	3.1	0.69
3-6	4.0	0.90
6-10	2.8	0.63
10-20	1.0	0.22
20+	0	0
SUBTOTAL 3+	7.8	1.75
TOTAL	10.9	2.44

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 2.0 in
5.08 cm

Average diameter, 3+fuels: 4.7 in
11.94 cm

Percent rotten, 3+fuels: 59 %

Volume of **sound** 3+fuels: 250 ft³/ac
17.5 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

LAOC	117 yrs
TSHE	90 yrs
PIMO	90 yrs
ABGR	80 yrs

Average slope 2 %
Aspect: northeast
Elevation: 2630 ft 799 m

Remarks:
Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: low
Torching: low
Crowning: low
Resistance to control: medium

Overall Fire Potential LOW

STAND LOCATION

National Forest: Kootenai
Ranger District: Libby
Drainage: W. Fk. Quartz Cr.

Photo taken: 6/27/78
By W. C. Fischer

DATA SHEET

Stand No. 17A

FOREST COVER TYPE: SAF NO. 228, Western redcedar

MONTANA HABITAT TYPE: NO. 532, Western redcedar/queencup beadlily-wild sarsparilla phase (THPL/CLUN-ARNU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.2	0.04
0.25-1	1.1	0.25
1-3	2.3	0.52
Subtotal 0-3	3.6	0.81
3-6	2.1	0.47
6-10	2.9	0.65
10-20	2.9	0.65
20+	0	0
SUBTOTAL 3+	7.9	1.77
TOTAL	11.5	2.58

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 3.1 in

7.87 cm

Average diameter, 3+fuels: 5.5 in

13.97 cm

Percent rotten, 3+fuels: 28 %

Volume of **sound** 3+fuels: 458 ft³/ac

32.1 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

POTR	100 yrs
THPL	80 yrs
ABGR	60 yrs

Average slope: 3 %

Aspect: southeast

Elevation: 2850 ft 869 m

Remarks:

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: nil

Crowning: nil

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Kootenai

Ranger District: Troy

Drainage: Ross Cr.

Photo taken: 6/28/78

By: W. C. Fischer

DATA SHEET

Stand No. 3A

FOREST COVER TYPE: SAF NO. 227, Western redcedar - Western hemlock

MONTANA HABITAT TYPE: NO. 571, Western hemlock/queencup beadlily-queencup beadlily phase (TSHE/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.4	0.09
0.25-1	1.1	0.25
1-3	1.5	0.34
Subtotal 0-3	3.0	0.68
3-6	1.8	0.40
6-10	4.1	0.92
10-20	4.4	0.99
20+	0	0
SUBTOTAL 3+	10.3	2.31
TOTAL	13.3	2.99

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 2.9 in 7.73 cm

Average diameter, 3+fuels: 6.0 in 15.24 cm

Percent rotten, 3+fuels: 36 %

Volume of **sound** 3+fuels: 527 ft³/ac 36.9 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

Average slope: 2 %

Aspect: northwest

Elevation: 2830 ft 863 m

Remarks: Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: nil

Crowning: nil

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Kootenai

Ranger District: Libby

Drainage: Quartz Cr.

Photo taken: 6/27/78

By: W. C. Fischer

DATA SHEET

Stand No. 13A

FOREST COVER TYPE: SAF NO. 227, Western redcedar - Western hemlock

MONTANA HABITAT TYPE: NO. 531, Western redcedar/queencup beadlily-queencup beadlily phase (THPL/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.4	0.09
0.25-1	2.0	0.45
1-3	0.9	0.20
Subtotal 0-3	3.3	0.74
3-6	3.3	0.74
6-10	4.7	1.05
10-20	3.4	0.76
20+	0	0
SUBTOTAL 3+	11.4	2.55
TOTAL	14.7	3.29

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H/G	8/10

OTHER FUEL DATA

Average duff depth: 3.5 in
8.89 cm

Average diameter, 3+fuels: 5.3 in
13.46 cm

Percent rotten, 3+fuels: 67 %

Volume of **sound** 3+fuels: 299 ft³/ac
20.9 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	100 yrs
THPL	95 yrs
ABGR	85 yrs
LACO	80 yrs

Average slope: 5 %
Aspect: southwest
Elevation: 3080 ft 939 m

Remarks:
Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: low
Crowning: low
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Kootenai
Ranger District: Libby
Drainage: Quartz Cr.

Photo taken: 6/27/78
By W. C. Fischer

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DATA SHEET

Stand No. 6A

FOREST COVER TYPE: SAF NO. 227, Western redcedar - Western hemlock

MONTANA HABITAT TYPE: NO. 531, Western redcedar/queencup beadlily-queencup beadlily phase (THPL/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.4	0.09
0.25-1	1.7	0.38
1-3	1.1	0.25
Subtotal 0-3	3.2	0.72
3-6	2.2	0.49
6-10	2.8	0.63
10-20	4.2	0.94
20+	4.6	1.03
SUBTOTAL 3+	13.8	3.09
TOTAL	17.0	3.81

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 3.1 in, 7.87 *cm*

Average diameter, 3+fuels: 6.5 in, 16.51 *cm*

Percent rotten, 3+fuels: 86 %

Volume of **sound** 3+fuels: 152 ft³/ac, 10.6 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants: TSHE 200 yrs

Average slope: 29 %

Aspect: northwest

Elevation: 3080 ft 939 *m*

Remarks:

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: low

Torching: low

Crowning: nil

Resistance to control: medium

Overall Fire Potential LOW

STAND LOCATION

National Forest: Kootenai

Ranger District: Libby

Drainage: W. Fk. Quartz Cr.

Photo taken: 6/27/78

By: W. C. Fischer

DATA SHEET

Stand No. 18A

FOREST COVER TYPE: SAF NO. 227, Western redcedar - Western hemlock

MONTANA HABITAT TYPE: NO. 531, Western redcedar/queencup beadlily-queencup beadlily phase (THPL/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.6	0.13
0.25-1	1.8	0.40
1-3	2.1	0.47
Subtotal 0-3	4.5	1.00
3-6	5.6	1.26
6-10	2.8	0.63
10-20	0.5	0.11
20+	4.3	0.96
SUBTOTAL 3+	13.2	2.96
TOTAL	17.7	3.96

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.9 in

4.83 cm

Average diameter, 3+fuels: 4.6 in

11.68 cm

Percent rotten, 3+fuels: 5 %

Volume of **sound** 3+fuels: 999 ft³/ac

69.9 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	90 yrs
THPL	80 yrs
LACO	80 yrs
ABGR	80 yrs

Average slope: 3 %

Aspect: southwest

Elevation: 2850 ft 869 m

Remarks:

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: low

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Kootenai

Ranger District: Troy

Drainage: Ross Cr.

Photo taken: 6/28/78

By: W. C. Fischer

DATA SHEET

Stand No. 10A

FOREST COVER TYPE: SAF NO. 227, Western redcedar - Western hemlock

MONTANA HABITAT TYPE: NO. 572, Western hemlock/queencup beadlily-wild sarsaparilla phase (TSHE/CLUN-ARNU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.4	0.09
0.25-1	1.5	0.34
1-3	1.4	0.31
Subtotal 0-3	3.3	0.74
3-6	1.4	0.31
6-10	6.8	1.52
10-20	4.6	1.03
20+	1.9	0.43
SUBTOTAL 3+	14.7	3.29
TOTAL	18.0	4.03

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 4.0 in
10.16 *cm*

Average diameter, 3+fuels: 6.8 in
17.27 *cm*

Percent rotten, 3+fuels: 46 %

Volume of **sound** 3+fuels: 641 ft³/ac
44.9 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

LACO	125 yrs
THPL	85 yrs
ABGR	85 yrs

Average slope: 2 %
Aspect: southwest
Elevation: 3000 ft 914 *m*

Remarks:

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: medium
Crowning: low
Resistance to control: low

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Kootenai
Ranger District: Libby
Drainage: W. Fk. Quartz Cr.

Photo taken: 6/27/78
By: W. C. Fischer

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DATA SHEET

Stand No. 7A

FOREST COVER TYPE: SAF NO. 227, Western redcedar - Western hemlock

MONTANA HABITAT TYPE: NO. 531, Western redcedar/queencup beadlily-queencup beadlily phase (THPL/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.4	0.09
0.25-1	1.7	0.38
1-3	3.2	0.72
Subtotal 0-3	5.3	1.19
3-6	1.7	0.38
6-10	7.9	1.77
10-20	4.6	1.03
20+	0	0
SUBTOTAL 3+	14.2	3.18
TOTAL	19.5	4.37

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H/G	8/10

OTHER FUEL DATA

Average duff depth: 3.5 in

8.89 *cm*

Average diameter, 3+fuels: 6.5 in

16.51 *cm*

Percent rotten, 3+fuels: 45 %

Volume of **sound** 3+fuels: 625 ft³/ac

43.7 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

THPL	210 yrs
PIMO	140 yrs
TSHE	140 yrs

Average slope: 4 %

Aspect: northwest

Elevation 2720 ft 829 *m*

Remarks:

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: medium

Torching: low

Crowning: nil

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Kootenai

Ranger District: Libby

Drainage: W. Fk. Quartz Cr.

Photo taken: 6/27/78

By W. C. Fischer

DATA SHEET

Stand No. 19A

FOREST COVER TYPE: SAF NO. 227, Wester redcedar - Wester hemlock

MONTANA HABITAT TYPE: NO. 571, Western hemlock/queencup beadlily-queencup beadlily phase (TSHE/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.3	0.07
0.25-1	1.2	0.27
1-3	1.6	0.36
Subtotal 0-3	3.1	0.70
3-6	5.3	1.19
6-10	9.5	2.13
10-20	2.5	0.56
20+	0	0
SUBTOTAL 3+	17.3	3.88
TOTAL	20.4	4.58

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.5 in

3.81 *cm*

Average diameter, 3+fuels: 5.1 in

12.95 *cm*

Percent rotten, 3+fuels: 21 %

Volume of **sound** 3+fuels: 1096 ft³/ac

76.7 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

THPL	85 yrs
LACO	85 yrs
TSHE	80 yrs
ABGR	70 yrs

Average slope: 2 %

Aspect: southeast

Elevation: 2590 ft 789 *m*

Remarks

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Kootenai

Ranger District: Troy

Drainage: Ross Cr.

Photo taken: 6/28/78

By: W. C. Fischer

DATA SHEET

Stand No. 11A

FOREST COVER TYPE: SAF NO. 227, Western redcedar - Western hemlock

MONTANA HABITAT TYPE: NO. 532, Western redcedar/queencup beadlily-wild sarsparilla (THPL/CLUN-ARUV)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.4	0.09
0.25-1	1.2	0.27
1-3	1.1	0.25
Subtotal 0-3	2.7	0.61
3-6	1.1	0.25
6-10	7.0	1.57
10-20	8.6	1.93
20+	1.4	0.31
SUBTOTAL 3+	18.1	4.06
TOTAL	20.8	4.66

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 2.4 in
6.10 cm

Average diameter, 3+fuels: 7.6 in
19.30 cm

Percent rotten, 3+fuels: 48 %

Volume of **sound** 3+fuels: 754 ft³/ac
52.8 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

ABGR	120 yrs
THPL	108 yrs
PSME	103 yrs

Average slope: 3 %
Aspect: southwest
Elevation: 2950 ft 899 m

Remarks.
Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90 ° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: low
Torching: low
Crowning: low
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Kootenai
Ranger District: Libby
Drainage: Quartz Cr.

Photo taken: 6/27/78
By W. C. Fischer

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DATA SHEET

Stand No. 5A

FOREST COVER TYPE: SAF NO. 224, Western hemlock

MONTANA HABITAT TYPE: NO. 571, Western hemlock/queencup beadlily-queencup beadlily phase (TSHE/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.6	0.13
0.25-1	1.2	0.27
1-3	0.8	0.18
Subtotal 0-3	2.6	0.58
3-6	4.7	1.05
6-10	15.5	3.47
10-20	0.9	0.20
20+	0	0
SUBTOTAL 3+	21.1	4.72
TOTAL	23.7	5.30

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.2 in, 5.59 cm

Average diameter, 3+fuels: 5.6 in, 14.22 cm

Percent rotten, 3+fuels: 35 %

Volume of **sound** 3+fuels: 1093 ft³/ac, 76.5 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

TSHE	95 yrs
PIMO	85 yrs

Average slope: 2 %

Aspect: southwest

Elevation: 2770 ft 844 m

Remarks:

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: low

Crowning: low

Resistance to control: high

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Kootenai

Ranger District: Libby

Drainage: W. Fk. Quartz Cr.

Photo taken: 6/27/78

By: W. C. Fischer

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DATA SHEET

Stand No. 8A

FOREST COVER TYPE: SAF NO. 227, Western redcedar - Western hemlock

MONTANA HABITAT TYPE: NO. 571, Western hemlock/queencup beadlily-queencup beadlily phase (TSHE/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.7	0.16
0.25-1	2.1	0.47
1-3	3.1	0.69
Subtotal 0-3	5.9	1.32
3-6	5.4	1.21
6-10	3.9	0.87
10-20	7.8	1.75
20+	4.1	0.92
SUBTOTAL 3+	21.2	4.75
TOTAL	27.1	6.07

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 3.0 in; 7.62 cm

Average diameter, 3+fuels: 5.6 in; 14.22 cm

Percent rotten, 3+fuels: 61 %

Volume of **sound** 3+fuels: 648 ft³/ac; 45.3 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

THPL	210 yrs
TSHE	119 yrs

Average slope: 30 %

Aspect: northwest

Elevation: 2750 ft 838 m

Remarks:

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: high

Torching: low

Crowning: low

Resistance to control: high

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Kootenai

Ranger District: Libby

Drainage: W. Fk. Quartz Cr.

Photo taken. 6/27/78

By W. C. Fischer

DATA SHEET

Stand No. 16A

FOREST COVER TYPE: SAF NO. 227, Western redcedar - Western hemlock

MONTANA HABITAT TYPE: NO. 571, Western hemlock/queencup beadlily-queencup beadlily phase (TSHE/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.6	0.13
0.25-1	2.2	0.49
1-3	2.5	0.56
Subtotal 0-3	5.3	1.18
3-6	9.3	2.08
6-10	21.1	2.71
10-20	3.2	0.72
20+	0	0
SUBTOTAL 3+	24.6	5.51
TOTAL	29.9	6.69

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 5.3 in
13.46 cm

Average diameter, 3+fuels:
5.1 in
12.95 cm

Percent rotten, 3+fuels: 40 %

Volume of **sound** 3+fuels:
1185 ft³/ac
82.9 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICEA	85 yrs
TSHE	75 yrs
ABGR	75 yrs

Average slope: 2 %
Aspect: northwest
Elevation: 2880 ft 878 m

Remarks: Natural Area

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: low

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Kootenai

Ranger District: Troy

Drainage: Ross Cr.

Photo taken 6/28/78

By W. C. Fischer

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DATA SHEET

Stand No. 15A

FOREST COVER TYPE: SAF NO. 227, Western redcedar - Western hemlock

MONTANA HABITAT TYPE: NO. 550, Western redcedar/devil's club (THPL/OPHP)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.2	0.04
0.25-1	1.1	0.25
1-3	1.0	0.22
Subtotal 0-3	2.3	0.51
3-6	0.4	0.09
6-10	1.3	0.29
10-20	3.2	0.72
20+	50.4	11.30
SUBTOTAL 3+	55.3	12.40
TOTAL	57.6	12.91

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.8 in
7.11 cm

Average diameter, 3+fuels:
16.6 in
42.16 cm

Percent rotten, 3+fuels: 40 %

Volume of **sound** 3+fuels:
2647 ft³/ac
185.2 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
THPL 400+ yrs

Average slope: 2 %
Aspect northeast
Elevation 2860 ft 872 m

Remarks: Natural Area
Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: low
Torching: nil
Crowning: nil
Resistance to control: medium

Overall Fire Potential LOW

STAND LOCATION

National Forest: Kootenai
Ranger District: Troy
Drainage: Ross Cr.

Photo taken 6/28/78
By W. C. Fischer

☆ U.S. GOVERNMENT PRINTING OFFICE: 1981-0-781-749

Fischer, William C.
1981. Photo guide for appraising downed woody fuels in Montana forests: Grand fir - larch - Douglas-fir, western hemlock, western redcedar - western hemlock, and western redcedar cover types. USDA For. Serv. Gen. Tech. Rep. INT-96, 53p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Four series of color photographs show different levels of downed woody material resulting from natural processes in four forest cover types in Montana. Each photo is supplemented by fuel inventory data and potential fire behavior ratings.

KEYWORDS: forest fuels, fire behavior, fire hazard, fuel appraisal

Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

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PHOTO GUIDE FOR APPRAISING DOWNED WOODY FUELS IN MONTANA FORESTS:

Interior Ponderosa Pine, Ponderosa Pine–Larch–Douglas-Fir, Larch–Douglas-Fir, and Interior Douglas-Fir Cover Types

William C. Fischer

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U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
OGDEN, UTAH 84401

THE AUTHOR

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RESEARCH SUMMARY

Two series of color photographs show different levels of downed woody material resulting from natural processes in two forest cover types in Montana. Each photo is supplemented by inventory data describing the size, weight, volume, and condition of the debris pictured. A subjective evaluation of potential fire behavior under an average bad fire weather situation is given.

Instructions are provided for using the photos to describe fuels and to evaluate potential fire hazard.

GENERAL TECHNICAL REPORT INT-97

PHOTO GUIDE FOR APPRAISING DOWNED WOODY FUELS IN MONTANA FORESTS:

Interior Ponderosa Pine, Ponderosa Pine–Larch–Douglas-Fir, Larch–Douglas-Fir, and Interior Douglas-Fir Cover Types

William C. Fischer

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
OGDEN, UTAH 84401

ACKNOWLEDGMENTS

The fire behavior potential ratings assigned to the photos in this guide are the result of on-site evaluation by the following fire managers and researchers:

Donald E. Abbott, Deerlodge National Forest
George F. Bissonette, Kootenai National Forest
Dr. James K. Brown, Northern Forest Fire Laboratory
Fred L. Cavill, Lolo National Forest
Farrell G. Cooper, Lolo National Forest
Ronald G. Curtiss, Kootenai National Forest
Walter L. De Zell, Bitterroot National Forest
John B. Dillon, Kootenai National Forest
Wyatt W. Frost, Bitterroot National Forest
Horace F. Goodwin, Custer National Forest
Del Goss, Helena National Forest
Patrick F. Hartless, Northern Forest Fire Laboratory
Roger O. Hearst, Lolo National Forest
Jerry A. Hinman, Bitterroot National Forest
Robert Kellogg, Helena National Forest
Douglas H. Mackay, Lewis and Clark National Forest
Jerrald W. Miller, Lolo National Forest
Robert W. Mutch, Lolo National Forest
Dr. Rodney A. Norum, Northern Forest Fire Laboratory[1]
John V. Puckett, Northern Region Aviation and Fire Management
Delmar L. Radtke, Northern Region Timber Management
Charles E. Rodgers, Lolo National Forest
Everett Stiger, Helena National Forest
Russell H. Trostad, Lewis and Clark National Forest
Walter J. Tomascak, Custer National Forest
Don V. Williams, Northern Region Aviation and Fire Management (Retired)
Jerry Williams, Montana State Division of Forestry

The author gratefully acknowledges the help received from these men and thanks them for their willingness to share their expertise. Nonan V. Noste, Northern Forest Fire Laboratory, conducted many of the fire behavior potential rating sessions. His help is also gratefully acknowledged.

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[1] Subsequently assigned to Institute of Northern Forestry, Fairbanks, Alaska.

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SERIES 2 - PONDEROSA PINE - LARCH - DOUGLAS-FIR SAF COVER TYPE 214 31

SERIES 3 - LARCH - DOUGLAS-FIR SAF COVER TYPE 212 57

SERIES 4 - INTERIOR DOUGLAS-FIR SAF COVER TYPE 210 95

PURPOSE OF PHOTO SERIES

unscheduled prescribed fires

PURPOSE OF PHOTO SERIES

This photo guide contains information that can be used to appraise the dead woody debris on the forest floor of interior ponderosa pine, ponderosa pine - larch - Douglas-fir, larch - Douglas-fir, and interior Douglas-fir. The guide is primarily for natural (nonslash) fuels, although some of the photos include old logging and thinning slash. Natural fuels result from wind, snow, and mechanical breakage, natural pruning of lower branches, needle fall, windthrow, blowdown, and the falling of trees killed by insects, disease, fire, and competition for light and moisture. The old logging and thinning slash shown has either been treated or left untreated. It can therefore be considered a part of the natural fuel complex.

This guide is designed to help forest managers describe the deadwood on the forest floor, to estimate the amount of such material, and to evaluate its fire hazard. The photos show a variety of fuel situations that exist in ponderosa pine, western larch, and Douglas-fir forests in Montana and surrounding Northern Rocky Mountain areas.

The fuel appraisal obtained from this guide can be used to plan fire management strategies including fire prevention, fuel treatment, prescribed fire, dispatching for fire suppression, and establishing criteria unscheduled prescribed fires.

The photos provide a relatively quick and inexpensive aid for accomplishing fuel appraisal over large forested areas. Although the precision of this procedure is unknown, it is expected to be intermediate: less than standard fuel inventory but greater than designating a stylized fuel model such as used in the National Fire Danger Rating System.

Perhaps the strongest feature of this series is the fire potential rating with each photo. Alternative methods for evaluating fire potential are generally unavailable, and those methods that do exist are outdated or not well suited for rating nonuniform fuel situations.

USING THE PHOTOS

Arranging the Photos

The photos and accompanying data sheets are presented in four series, one for each cover type:

Series 1—Interior ponderosa pine cover type.
Series 2—Ponderosa pine - larch - Douglas-fir cover type.
Series 3—Larch - Douglas-fir cover type.
Series 4—Interior Douglas-fir cover type.

Within each series, the photos are arranged according to total fuel loading. The first photo in each series shows the lightest fuel load, the last shows the heaviest load.

The Data Sheet

The fuel complex shown in each photo is described on an accompanying data sheet in terms of the following characteristics:

1. Forest cover type.
2. Montana habitat type.
3. Stand and site data: age of overstory dominants, average slope, aspect, elevation, and fire ecology group.
4. Down and dead woody fuel loadings by size class.
5. Other fuel data: average duff depth and for fuels 3 inches (7.62 cm) in diameter and greater, the average diameter, the percent rotten, and the volume of sound material.
6. National Fire Danger Rating System fuel model.
7. Stylized fuel model.

Symbols used for forest vegetation are the standard symbols for Northern Region plants (USDA Forest Service 1969). The symbols represent the first two letters of the generic name and the first two letters of the specific name of the plant species (such as PIPO - *Pinus ponderosa*).

Describing the Fuel Complex

Several important fuel characteristics can be seen in each photo: (1) The amount of fuel in the different diameter classes, (2) the general condition of the fuel (sound versus rotten), (3) the distribution of the fuel over the area, and (4) the depth of the fuel (each black and white section on the plot marker is 1 foot [0.3048 m]). Consequently, the manager can use the photos to estimate values for these characteristics of woody debris on the forest floor.

To use the photos to describe downed woody fuels, simply inspect the fuel complex and then select the photo that most nearly compares with what is on the ground. Then use the information on the data sheet to describe the observed fuel complex.

Perhaps no one photo adequately represents the actual situation. If this is the case, select two photos that bracket the observed fuel complex and then interpolate between the values on the data sheets accompanying the selected photos.

Rather than trying to select one photo or a pair of photos that best reflects the entire fuel complex, the user could describe each of the above-mentioned fuel characteristics separately. This could be done by using the following procedure suggested by Maxwell and Ward (1976a, 1976b) as adapted by Koski and Fischer (1979):

1. Observe each of the characteristics of the fuel complex on the ground.
2. For each characteristic, select the photo that most nearly matches, or photos that bracket the observed situations.
3. For each characteristic, obtain a value from the data sheet accompanying the selected photo (or interpolate a value if a pair of photos was selected).

The above procedure should only be used when a single photo or a pair of photos can't be used to describe the observed situation. For most fuel situations, any improvement in estimates obtained by rating each fuel characteristic separately is not justified by the increased time it takes to get them.

These procedures refer to use of the photos at a specific point. This can be a representative point and the results applied to an entire forest stand. This method is satisfactory when the fuels are uniform throughout the stand. It will be difficult to select a representative point in many stands. The photos can be used to sample stands when nonuniform fuels preclude the selection of a representative point. The procedure is as follows:

1. Establish 10 or more points, spread systematically through the stand.
2. At each point evaluate the fuels within clear eyesight.
3. Summarize the results as a simple average for the stand or express the results as the percent of area in several classes (for example, 40 percent of stand >10 tons/acre, 60 percent of stand <30 tons/acre).

Rating Fire Potential

The data sheet for each photo contains adjective ratings for five different expressions of fire behavior: rate of spread, intensity, torching, crowning, and resistance to control. An overall fire behavior potential rating is also given for the fuel complex pictured. The ratings are for an "average bad" fire weather situation defined as: 80°-90° F temperature (27°-32° C), 15-20 percent relative humidity, 10-15 mi/h windspeed (16-24 km/h), and 4 weeks since a significant rain (0.10 inch [0.25 cm] or greater).

This approach to estimating fire potential is not without precedent in the Northern Rocky Mountains. In many ways it is a refinement of the time tested concept of fuel rating introduced more than 40 years ago by L. G. Hornby (1936).

The adjective ratings nil, low, medium, high, and extreme are defined as follows for each of the different expressions of fire behavior:

Rate of Spread

Nil—fire cannot sustain itself.

Low—spread will be slow and discontinuous.

Medium—uniform spread possible, but can be stopped by aggressive ground attack with hand tools.

High—spread will be rapid; indirect attack on fire front may be required for control.

Extreme—spread will be explosive; little chance of control until weather changes.

Intensity

Nil—fire cannot sustain itself.

Low—cool fire; very little hot spotting required for control.

Medium—fire will burn hot in places; aggressive hot spotting with hand tools likely to be successful.

High—too hot for sustained direct attack with hand tools; aerial tankers or large ground tanker required to cool fire front.

Extreme—direct ground attack not possible; air or ground tanker attack likely to be ineffective.

Torching

Nil—no chance of torching.

Low—occasional tree may torch-out.

Medium—pole-sized understory trees likely to torch-out.

High—Most of understory and occasional overstory trees likely to torch-out.

Extreme—entire stand likely to torch-out.

Crowning

Nil—sustained spread in crowns will not occur.

Low—sustained spread in crowns unlikely.

Medium—some crowning likely but will not be continous.

High—sustained crowning likely.

Extreme—sustained crowning will occur.

Resistance to Control

Nil—no physical impediments to line building and holding.

Low—occasional tough spots but not enough to cause serious line building and holding problems.

Medium—hand line construction will be difficult and slow, but dozers can operate without serious problems.

High—slow work for dozers, very difficult for hand crews; hand line holding will be difficult.

Extreme—neither dozers nor hand crews can effectively build and hold line.

Nil—no chance of torching

Overall

Nil—fire will not sustain itself.

Low—fire can be easily controlled by several smokechasers with hand tools.

Medium—aggressive crew-sized (6-10 persons) initial attack required for successful control.

High—aggressive crew-sized (25 persons) initial attack with substantial reinforcement required for successful control; 10 percent chance that initial control action will fail.

Extreme—90 percent chance that initial control action will fail.

Procedures for using the photos to estimate fire potential are the same as those given for describing the fuel complex.

PHOTO GUIDE DEVELOPMENT

This photo guide was developed using the technique explained by Fischer (1981), which involved the following steps:

1. The fuel complexes photographed were selected to represent the range of fuel situations observed to exist for the cover type in Montana.
2. Sample plots are generally laid out and photographed in accordance with procedures suggested by USDA Forest Service (1975).
3. Fuels were sampled and described using fuel inventory and computational techniques developed by Brown (1974).
4. Habitat types are according to Pfister and others (1977). Cover types are according to SAF (1954).
5. Fire potential ratings are based on subjective evaluation by experienced fire managers using the adjective ratings and definitions in the preceding section of this guide.
6. National Fire Danger Rating fuel model assignment was by the author using definitions provided by Deeming and others (1977). Stylized fuel model assignment was by the author using definitions provided by Albini (1976).
7. The fire ecology group assignment was by the author using the definitions provided by Davis and others (1980).
8. Stand and site data were obtained using standard forestry field techniques.

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DATA SHEET

Stand No. 24

FOREST COVER TYPE: SAF NO. 237, Interior ponderosa pine

MONTANA HABITAT TYPE: NO. 142, Ponderosa pine/Idaho fescue-Idaho fescue phase (PIPO/FEID-FEID)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0	0
0.25-1	0.6	0.13
1-3	0.4	0.09
Subtotal 0-3	1.0	0.22
3-6	0.1	0.02
6-10	0	0
10-20	0	0
20+	0	0
SUBTOTAL 3+	0.1	0.02
TOTAL	1.1	0.24

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
U	9

OTHER FUEL DATA

Average duff depth: 1.5 in
3.81 cm

Average diameter, 3+fuels:
4.0 in
10.16 cm

Percent rotten, 3+fuels: 0 %

Volume of **sound** 3+fuels:
9 ft³/ac
0.6 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
PIPO 137 yrs

Average slope: 10 %
Aspect: south
Elevation: 3100 ft 945 m

Remarks.

Fire Ecology Group Two

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: nil

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Ninemile

Drainage: Ninemile Cr.

Photo taken: 9/24/76

By: W. C. Fischer

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8

DATA SHEET

Stand No. 18

FOREST COVER TYPE: SAF NO. 237, Interior ponderosa pine

MONTANA HABITAT TYPE: NO. 313, Douglas-fir/snowberry-snowberry phase (PSME/SYAL-SYAL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.3	0.07
0.25-1	0.6	0.13
1-3	1.1	0.25
Subtotal 0-3	2.0	0.45
3-6	0.7	0.16
6-10	0.4	0.09
10-20	0	0
20+	0	0
SUBTOTAL 3+	1.1	0.25
TOTAL	3.1	0.70

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
C/U	2/9

OTHER FUEL DATA

Average duff depth: 0.7 in

1.78 cm

Average diameter, 3+fuels: 4.0 in

10.16 cm

Percent rotten, 3+fuels: 11 %

Volume of **sound** 3+fuels: 85 ft^3/ac

6.0 m^3/ha

STAND AND SITE DATA

Age of overstory dominants:

PIPO 87 yrs

PSME 67 yrs

Average slope 20 %

Aspect west

Elevation 3210 ft 978 m

Remarks

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: low

Torching: nil

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Ninemile

Drainage: Mill Cr.

Photo taken: 9/22/76

By W. C. Fischer

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3

DATA SHEET

Stand No. 23

FOREST COVER TYPE: SAF NO. 237, Interior ponderosa pine

MONTANA HABITAT TYPE: NO. 130, Ponderosa pine/bluebunch wheatgrass (PIPO/AGSP)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.2	0.04
0.25-1	0.3	0.07
1-3	0.9	0.20
Subtotal 0-3	1.4	0.31
3-6	1.1	0.25
6-10	0.3	0.07
10-20	1.0	0.22
20+	0	0
SUBTOTAL 3+	2.4	0.54
TOTAL	3.8	0.85

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
U	9

OTHER FUEL DATA

Average duff depth: 0.6 in
1.52 *cm*

Average diameter, 3+fuels: 4.9 in
12.45 *cm*

Percent rotten, 3+fuels: 13 %

Volume of **sound** 3+fuels: 171 ft³/ac
12.0 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:
PIPO 67 yrs

Average slope: 19 %
Aspect: southeast
Elevation: 3100 ft 945 *m*

Remarks:
Fire Ecology Group Two

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: low
Torching: low
Crowning: low
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo
Ranger District: Ninemile
Drainage: Ninemile Cr.

Photo taken: 9/24/76
By W. C. Fischer

DATA SHEET

Stand No. 33A

FOREST COVER TYPE: SAF NO. 237, Interior ponderosa pine

MONTANA HABITAT TYPE: NO. 171, Ponderosa pine/snowberry-creeping Oregon grape phase (PIPO/SYAL-BERE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	1.0	0.22
1-3	0.5	0.11
Subtotal 0-3	1.8	0.40
3-6	0.5	0.11
6-10	0.2	0.04
10-20	3.2	0.72
20+	0	0
SUBTOTAL 3+	3.9	0.87
TOTAL	5.7	1.27

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
U	9

OTHER FUEL DATA

Average duff depth: 1.7 in 4.32 cm

Average diameter, 3+ fuels: 8.9 in 22.61 cm

Percent rotten, 3+ fuels: 87 %

Volume of **sound** 3+ fuels: 42 ft³/ac 2.9 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
PIPO 180 yrs

Average slope: 10 %
Aspect: north
Elevation: 4160 ft 1268 m

Remarks:

Fire Ecology Group Three

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: high

Intensity: high

Torching: high

Crowning: extreme

Resistance to control: medium

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Custer

Ranger District: Ft. Howes

Drainage: Stocker Branch Cr.

Photo taken: 8/9/78

By W. C. Fischer

DATA SHEET

Stand No. 30A

FOREST COVER TYPE: SAF NO. 237, Interior ponderosa pine

MONTANA HABITAT TYPE: NO. 171, Ponderosa pine/snowberry-creeping Oregon grape phase (PIPO/SYAL-BERE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.2	0.04
0.25-1	0.6	0.13
1-3	1.9	0.43
Subtotal 0-3	2.7	0.60
3-6	0.7	0.16
6-10	2.4	0.54
10-20	0.9	0.20
20+	0	0
SUBTOTAL 3+	4.0	0.90
TOTAL	6.7	1.50

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
U	9

OTHER FUEL DATA

Average duff depth: 1.1 in
2.79 *cm*

Average diameter, 3+fuels: 5.8 in
14.73 *cm*

Percent rotten, 3+fuels: 79 %

Volume of **sound** 3+fuels: 67 ft³/ac
4.7 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:
PIPO 60 yrs

Average slope: 5 %
Aspect: northeast
Elevation: 4460 ft 1359 *m*

Remarks
Fire Ecology Group Three

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: medium

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Custer

Ranger District: Ft. Howes

Drainage: Stocker Branch Cr.

Photo taken: 8/9/78

By W. C. Fischer

3
2

DATA SHEET

Stand No. 32A

FOREST COVER TYPE: SAF NO. 237, Interior ponderosa pine

MONTANA HABITAT TYPE: NO. 141, Ponderosa pine/Idaho fescue-Idaho fescue phase (PIPO/FEID-FEID)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.5	0.11
0.25-1	1.9	0.43
1-3	4.5	1.01
Subtotal 0-3	6.9	1.55
3-6	1.0	0.22
6-10	2.5	0.56
10-20	0	0
20+	0	0
SUBTOTAL 3+	3.5	0.78
TOTAL	10.4	2.33

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.1 in

2.79 *cm*

Average diameter, 3+fuels: 4.3 in

10.92 *cm*

Percent rotten, 3+fuels: 53 %

Volume of **sound** 3+fuels: 130 ft³/ac

9.1 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PIPO 58 yrs

Average slope: 3 %

Aspect: southwest

Elevation: 4180 ft 1274 *m*

Remarks

Fire Ecology Group Two

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: high

Intensity: high

Torching: high

Crowning: high

Resistance to control: medium

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Custer

Ranger District: Ft. Howes

Drainage: Stocker Branch Cr.

Photo taken: 8/9/78

By W. C. Fischer

NATIONAL

DATA SHEET

Stand No. 17

FOREST COVER TYPE: SAF NO. 237, Interior ponderosa pine

MONTANA HABITAT TYPE: NO. 313, Douglas-fir/snowberry-snowberry phase (PSME/SYAL-SYAL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.1	0.02
0.25-1	1.1	0.25
1-3	2.7	0.61
Subtotal 0-3	3.9	0.88
3-6	4.2	0.94
6-10	2.3	0.52
10-20	0	0
20+	0	0
SUBTOTAL 3+	6.5	1.46
TOTAL	10.4	2.34

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
U	9

OTHER FUEL DATA

Average duff depth: 2.7 in
6.86 cm

Average diameter, 3+fuels: 4.3 in
10.92 cm

Percent rotten, 3+fuels: 5 %

Volume of **sound** 3+fuels: 494 ft³/ac
34.6 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PIPO	87 yrs
PSME	67 yrs

Average slope: 30 %
Aspect: west
Elevation: 3310 ft 1009 m

Remarks

Fire Ecology Group Two

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: low
Torching: nil
Crowning: nil
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo
Ranger District: Ninemile
Drainage: Mill Cr.

Photo taken: 9/22/76
By W. C. Fischer

DATA SHEET

Stand No. 31A

FOREST COVER TYPE: SAF NO. 237, Interior ponderosa pine

MONTANA HABITAT TYPE: NO. 141, Ponderosa pine/Idaho fescue-Idaho fescue phase (PIPO/FEID-FEID)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.2	0.04
0.25-1	0.4	0.09
1-3	0.7	0.16
Subtotal 0-3	1.3	0.29
3-6	1.0	0.22
6-10	2.9	0.65
10-20	5.5	1.23
20+	0	0
SUBTOTAL 3+	9.4	2.10
TOTAL	10.7	2.39

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
U	9

OTHER FUEL DATA

Average duff depth: 0.8 in

2.03 cm

Average diameter, 3+fuels: 7.5 in

19.05 cm

Percent rotten, 3+fuels: 80 %

Volume of **sound** 3+fuels: 154 ft³/ac

10.8 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PIPO 148 yrs

Average slope: 7 %

Aspect northeast

Elevation 4160 ft 1268 m

Remarks

Fire Ecology Group Two

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: high

Intensity: high

Torching: high

Crowning: high

Resistance to control: medium

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Custer

Ranger District: Ft. Howes

Drainage: Stocker Branch Cr.

Photo taken: 8/9/78

By W. C. Fischer

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9

DATA SHEET

Stand No. 29A

FOREST COVER TYPE: SAF NO. 237, Interior ponderosa pine

MONTANA HABITAT TYPE: NO. 141, Ponderosa pine/Idaho fescue-Idaho fescue phase (PIPO/FEID-FEID)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.2	0.04
0.25-1	1.3	0.29
1-3	3.2	0.72
Subtotal 0-3	4.7	1.05
3-6	3.4	0.76
6-10	0.9	0.20
10-20	2.4	0.54
20+	0	0
SUBTOTAL 3+	6.7	1.50
TOTAL	11.4	2.55

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
C	2

OTHER FUEL DATA

Average duff depth: 0.4 in
1.02 cm

Average diameter, 3+fuels:
4.3 in
10.92 cm

Percent rotten, 3+fuels: 29 %

Volume of **sound** 3+fuels:
381 ft³/ac
26.7 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
PIPO 100 yrs

Average slope: 7 %
Aspect: northwest
Elevation: 4430 ft 1350 m

Remarks: old burn

Fire Ecology Group Two

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: low

Torching: nil

Crowning: nil

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Custer

Ranger District: Ft. Howes

Drainage: Cow Cr.

Photo taken: 8/9/78

By W. C. Fischer

7
2

DATA SHEET

Stand No. 72

FOREST COVER TYPE: SAF NO. 237, Interior ponderosa pine

MONTANA HABITAT TYPE: NO. 171, Ponderosa pine/snowberry-snowberry phase (PIPO/SYAL-SYAL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.1	0.02
0.25-1	2.2	0.49
1-3	4.4	0.99
Subtotal 0-3	6.7	1.50
3-6	5.3	1.19
6-10	2.3	0.52
10-20	2.1	0.47
20+	0	0
SUBTOTAL 3+	9.7	2.18
TOTAL	16.4	3.68

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.1 in, 5.33 cm

Average diameter, 3+fuels: 4.4 in, 11.18 cm

Percent rotten, 3+fuels: 55 %

Volume of **sound** 3+fuels: 355 ft³/ac, 24.8 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
PIPO 80 yrs

Average slope 26 %
Aspect southeast
Elevation 3880 ft 1183 m

Remarks

Fire Ecology Group Two

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: high

Crowning: high

Resistance to control: low

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Woods Gulch

Photo taken: 7/27/77

By: W. C. Fischer

SERIES 2

PONDEROSA PINE - LARCH - DOUGLAS-FIR

SAF COVER TYPE 214

7
6

DATA SHEET

Stand No. 76

FOREST COVER TYPE: SAF NO. 214, Ponderosa pine - larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 261, Douglas-fir/ninebark-ninebark phase (PSME/PHMA-PHMA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.1	0.02
0.25-1	0.9	0.20
1-3	0.8	0.18
Subtotal 0-3	1.8	0.40
3-6	0.6	0.13
6-10	0.1	0.02
10-20	0	0
20+	0	0
SUBTOTAL 3+	0.7	0.15
TOTAL	2.5	0.55

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
C/U	2/9

OTHER FUEL DATA

Average duff depth: 1.0 in
2.54 cm

Average diameter, 3+fuels: 3.9 in
9.91 cm

Percent rotten, 3+fuels: 65 %

Volume of **sound** 3+fuels: 20 ft³/ac
1.4 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
PIPO 214 yrs
PSME 57 yrs

Average slope 10 %
Aspect. southwest
Elevation: 4900 ft 1494 m

Remarks

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90 ° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Woods Gulch

Photo taken: 7/27/77

By W. C. Fischer

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DATA SHEET

Stand No. 69

FOREST COVER TYPE: SAF NO. 214, Ponderosa pine - larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 261, Douglas-fir/ninebark-ninebark phase (PSME/PHMA-PHMA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.3	0.07
0.25-1	0.8	0.18
1-3	0.3	0.07
Subtotal 0-3	1.4	0.32
3-6	0.3	0.07
6-10	0.2	0.04
10-20	0.6	0.13
20+	0	0
SUBTOTAL 3+	1.1	0.24
TOTAL	2.5	0.56

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.5 in, 3.81 *cm*

Average diameter, 3+fuels: 5.1 in, 12.95 *cm*

Percent rotten, 3+fuels: 38 %

Volume of **sound** 3+fuels: 56 ft³/ac, 3.9 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PIPO	125 yrs
PSME	55 yrs

Average slope: 23 %

Aspect: southwest

Elevation 3780 ft 1152 *m*

Remarks

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: high

Crowning: medium

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Rattlesnake Cr.

Photo taken 7/15/77

By W. C. Fischer

DATA SHEET

Stand No. 80

FOREST COVER TYPE: SAF NO. 214, Ponderosa pine - larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 293, Douglas-fir/twinflower-blue huckleberry phase (PSME/LIBO-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.3	0.07
0.25-1	0.8	0.18
1-3	0.7	0.16
Subtotal 0-3	1.8	0.41
3-6	0.8	0.18
6-10	1.1	0.25
10-20	0	0
20+	0	0
SUBTOTAL 3+	1.9	0.43
TOTAL	3.7	0.84

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.5 in
3.81 *cm*

Average diameter, 3+fuels: 4.3 in
10.92 *cm*

Percent rotten, 3+fuels: 74 %

Volume of **sound** 3+fuels: 42 ft³/ac
2.9 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:
LAOC 280 yrs
PSME 133 yrs

Average slope: 60 %
Aspect northwest
Elevation: 4660 ft 1420 *m*

Remarks:
Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: high
Crowning: medium
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Woods Gulch

Photo taken: 7/28/77
By: W. C. Fischer

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DATA SHEET

Stand No. 70

FOREST COVER TYPE: SAF NO. 214, Ponderosa pine - larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 261, Douglas-fir/ninebark-ninebark phase (PSME/PHMA-PHMA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.4	0.09
0.25-1	1.4	0.31
1-3	1.1	0.25
Subtotal 0-3	2.9	0.65
3-6	3.2	0.72
6-10	0.7	0.16
10-20	1.4	0.31
20+	0	0
SUBTOTAL 3+	5.3	1.19
TOTAL	8.2	1.84

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.2 in

3.05 cm

Average diameter, 3+fuels:

4.6 in

11.68 cm

Percent rotten, 3+fuels: 92 %

Volume of **sound** 3+fuels:

36 ft³/ac

2.5 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PIPO	75 yrs
PSME	72 yrs

Average slope: 20 %

Aspect: southeast

Elevation: 3750 ft 1143 m

Remarks:

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Rattlesnake Cr.

Photo taken: 7/15/77

By: W. C. Fischer

DATA SHEET

Stand No. 64

FOREST COVER TYPE: SAF NO. 214, Ponderosa pine - larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 261, Douglas-fir/ninebark-ninebark phase (PSME/PHMA-PHMA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.2	0.04
0.25-1	0.7	0.16
1-3	0.8	0.18
Subtotal 0-3	1.7	0.38
3-6	3.4	0.76
6-10	4.3	0.96
10-20	0	0
20+	0	0
SUBTOTAL 3+	7.7	1.72
TOTAL	9.4	2.10

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.6 in

4.06 *cm*

Average diameter, 3+fuels: 4.6 in

11.68 *cm*

Percent rotten, 3+fuels: 70 %

Volume of **sound** 3+fuels: 180 ft³/ac

12.6 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PIPO	128 yrs
LAOC	110 yrs
ABGR	92 yrs

Average slope 20 %

Aspect southeast

Elevation: 4260 ft 1298 *m*

Remarks

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: low

Torching: low

Crowning: low

Resistance to control: medium

Overall Fire Potential LOW

STAND LOCATION

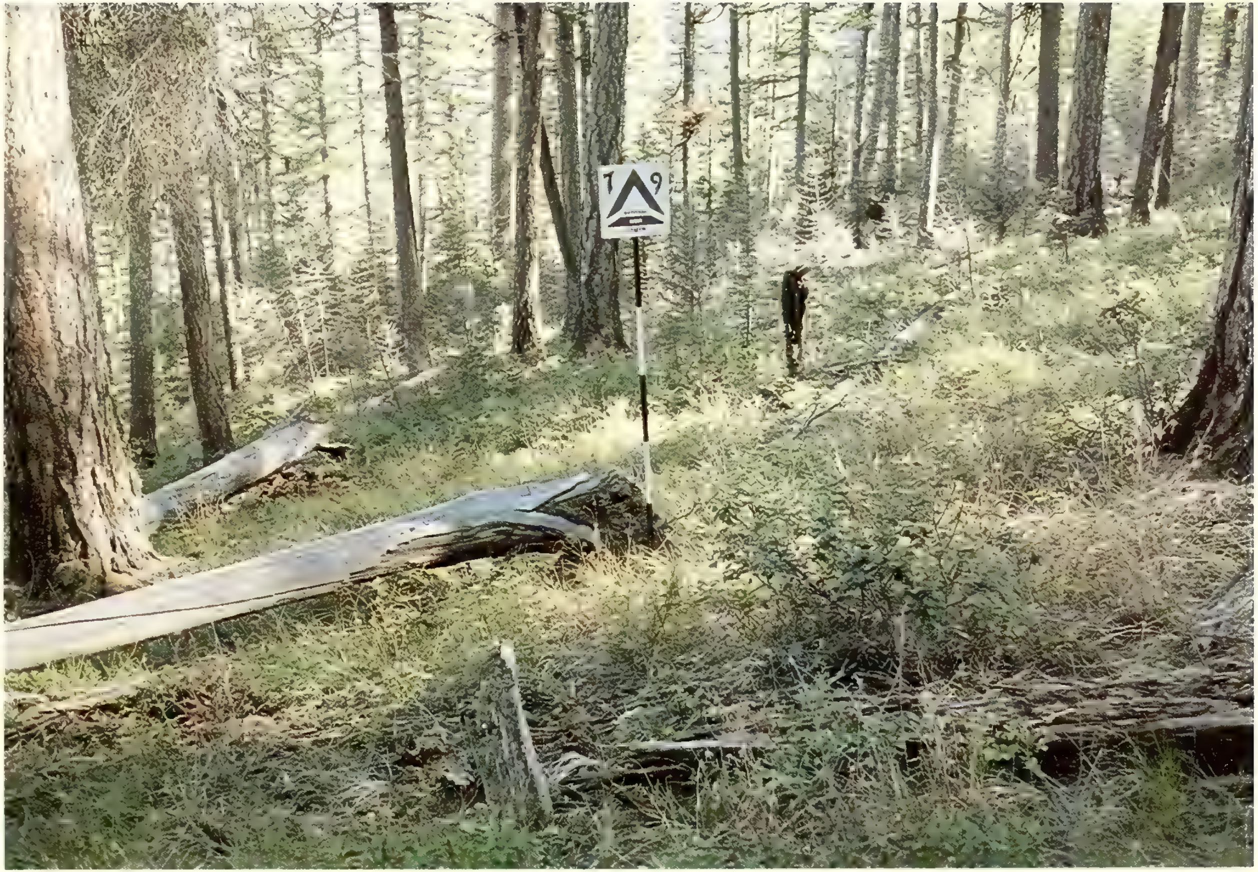
National Forest: Lolo

Ranger District: Missoula

Drainage: Rattlesnake Cr.

Photo taken: 7/14/77

By W. C. Fischer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DATA SHEET

Stand No. 79

FOREST COVER TYPE: SAF NO. 214, Ponderosa pine - larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 282, Douglas-fir/blue huckleberry-kinnikinnick phase (PSME/VAGL-ARUV)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.2	0.04
0.25-1	0.7	0.16
1-3	0.5	0.11
Subtotal 0-3	1.4	0.31
3-6	3.1	0.69
6-10	5.1	1.14
10-20	0.8	0.18
20+	0	0
SUBTOTAL 3+	9.0	2.01
TOTAL	10.4	2.32

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.8 in
4.57 cm

Average diameter, 3+fuels:
5.1 in
12.95 cm

Percent rotten, 3+fuels: 26 %

Volume of **sound** 3+fuels:
526 ft³/ac
36.8 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

LAOC	280 yrs
PIPO	270 yrs
PSME	133 yrs
PICO	27 yrs

Average slope: 30 %
Aspect: northwest
Elevation: 4730 ft 1442 m

Remarks
Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: low
Crowning: low
Resistance to control: low

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest Lolo
Ranger District: Missoula
Drainage Woods Gulch

Photo taken 7/28/77
By W. C. Fischer

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DATA SHEET

Stand No. 75

FOREST COVER TYPE: SAF NO. 214, Ponderosa pine - larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 261, Douglas-fir/ninebark-ninebark phase (PSME/PHMA-PHMA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.5	0.11
0.25-1	1.4	0.31
1-3	4.6	1.03
Subtotal 0-3	6.5	1.45
3-6	3.1	0.69
6-10	0.5	0.11
10-20	0.7	0.16
20+	0	0
SUBTOTAL 3+	4.3	0.96
TOTAL	10.8	2.41

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
U	9

OTHER FUEL DATA

Average duff depth: 1.2 in

3.05 *cm*

Average diameter, 3+fuels:

3.6 in

9.14 *cm*

Percent rotten, 3+fuels: 37 %

Volume of **sound** 3+fuels:

211 ft³/ac

14.8 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PIPO 65 yrs

PSME 64 yrs

Average slope: 10 %

Aspect: southwest

Elevation: 4480 ft 1366 *m*

Remarks

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: low

Resistance to control: low

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Woods Gulch

Photo taken: 7/27/77

By W. C. Fischer

DATA SHEET

Stand No. 73

FOREST COVER TYPE: SAF NO. 214, Ponderosa pine - larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 261, Douglas-fir/ninebark-ninebark phase (PSME/PHMA-PHMA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.5	0.11
0.25-1	1.0	0.22
1-3	1.1	0.25
Subtotal 0-3	2.6	0.58
3-6	1.8	0.40
6-10	5.6	1.26
10-20	1.5	0.34
20+	0	0
SUBTOTAL 3+	8.9	2.00
TOTAL	11.5	2.58

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.2 in
3.05 cm

Average diameter, 3+ fuels:
6.0 in
15.24 cm

Percent rotten, 3+ fuels: 68 %

Volume of **sound** 3+ fuels:
230 ft³/ac
16.1 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PIPO	172 yrs
PSME	110 yrs

Average slope: 40 %
Aspect: southeast
Elevation: 4080 ft 1244 m

Remarks
Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: low
Torching: low
Crowning: low
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Woods Gulch

Photo taken 7/27/77
By W. C. Fischer

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DATA SHEET

Stand No. 77

FOREST COVER TYPE: SAF NO. 214, Ponderosa pine - larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 322, Douglas-fir/pinegrass-kinnikinnick phase (PSME/CARU-ARUV)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.1	0.02
0.25-1	0.5	0.11
1-3	0.8	0.18
Subtotal 0-3	1.4	0.31
3-6	0.1	0.02
6-10	2.0	0.45
10-20	8.8	1.97
20+	0	0
SUBTOTAL 3+	10.9	2.44
TOTAL	12.3	2.75

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.7 in
4.32 cm

Average diameter, 3+fuels:
9.3 in
23.62 cm

Percent rotten, 3+fuels: 81 %

Volume of **sound** 3+fuels:
167 ft³/ac
11.7 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PIPO	190 yrs
PSME	188 yrs
LAOC	145 yrs

Average slope: 20 %
Aspect: southwest
Elevation 4780 ft 1457 m

Remarks

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: medium
Crowning: low
Resistance to control: low

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Woods Gulch

Photo taken: 7/28/77
By: W. C. Fischer

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4

DATA SHEET

Stand No. 84

FOREST COVER TYPE: SAF NO. 214, Ponderosa pine - larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 283, Douglas-fir/blue huckleberry-beargrass phase (PSME/VAGL-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.7	0.16
0.25-1	2.3	0.52
1-3	2.0	0.45
Subtotal 0-3	5.0	1.13
3-6	4.3	0.96
6-10	8.0	1.79
10-20	1.3	0.29
20+	0	0
SUBTOTAL 3+	13.6	3.04
TOTAL	18.6	4.17

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
J	12

OTHER FUEL DATA

Average duff depth: 0.8 in

2.03 cm

Average diameter, 3+fuels: 5.1 in

12.95 cm

Percent rotten, 3+fuels: 0 %

Volume of **sound** 3+fuels: 1093 ft³/ac

76.5 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

LAOC 71 yrs

PIPO 60 yrs

PSME 60 yrs

Average slope 20 %

Aspect southwest

Elevation 5470 ft 1667 m

Remarks: old thinning slash

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: low

Resistance to control: medium

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Howard Cr.

Photo taken 8/22/77

By: W. C. Fischer

DATA SHEET

Stand No. 74

FOREST COVER TYPE: SAF NO. 214, Ponderosa pine - larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 261, Douglas-fir/ninebark-ninebark phase (PSME/PHMA-PHMA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.9	0.20
0.25-1	1.7	0.38
1-3	3.6	0.81
Subtotal 0-3	6.2	1.39
3-6	4.0	0.90
6-10	4.5	1.01
10-20	1.8	0.40
20+	3.7	0.83
SUBTOTAL 3+	14.0	3.14
TOTAL	20.2	4.53

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.9 in

4.83 *cm*

Average diameter, 3+fuels: 5.0 in

12.70 *cm*

Percent rotten, 3+fuels: 32 %

Volume of **sound** 3+fuels: 758 ft³/ac

53.0 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PIPO	173 yrs
PSME	56 yrs

Average slope: 40 %

Aspect: southeast

Elevation: 4300 ft 1311 *m*

Remarks: Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: medium

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Woods Gulch

Photo taken 7/27/77

By W. C. Fischer

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8

DATA SHEET

Stand No. 78

FOREST COVER TYPE: SAF NO. 214, Ponderosa pine - larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 293, Douglas-fir/twinflower-blue huckleberry phase (PSME/LIBO-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.2	0.04
0.25-1	1.1	0.25
1-3	1.7	0.38
Subtotal 0-3	3.0	0.67
3-6	3.3	0.74
6-10	0.7	0.16
10-20	31.0	6.95
20+	0	0
SUBTOTAL 3+	35.0	7.85
TOTAL	38.0	8.52

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.9 in, 4.83 cm

Average diameter, 3+fuels: 8.4 in, 21.34 cm

Percent rotten, 3+fuels: 46 %

Volume of **sound** 3+fuels: 1505 ft³/ac, 105.3 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PIPO	320 yrs
LAOC	224 yrs
PSME	70 yrs

Average slope: 30 %

Aspect: northwest

Elevation: 4800 ft, 1463 m

Remarks: Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: medium

Resistance to control: medium

Overall Fire Potential: MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Woods Gulch

Photo taken: 7/28/77

By W. C. Fischer

SERIES 3

LARCH - DOUGLAS-FIR

SAF COVER TYPE 212

6 8

DATA SHEET

Stand No. 68

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 322, Douglas-fir/pinegrass-kinnikinnick phase (PSME/CARU-ARUV)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.5	0.11
0.25-1	0.7	0.16
1-3	0.2	0.04
Subtotal 0-3	1.4	0.31
3-6	0	0
6-10	0	0
10-20	0	0
20+	0	0
SUBTOTAL 3+	0	0
TOTAL	1.4	0.31

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.8 in

4.57 *cm*

Average diameter, 3+fuels: 0 in

0 *cm*

Percent rotten, 3+fuels: 0 %

Volume of **sound** 3+fuels: 0 ft³/ac

0 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

LAOC 50 yrs

PSME 50 yrs

PICO 50 yrs

Average slope: 1 %

Aspect: northeast

Elevation: 3930 ft 1198 *m*

Remarks:

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District Missoula

Drainage: Rattlesnake Cr.

Photo taken: 7/14/77

By W. C. Fischer

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1

DATA SHEET

Stand No. 31

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 261, Douglas-fir/ninebark-ninebark phase (PSME/PHMA-PHMA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.5	0.11
0.25-1	1.2	0.27
1-3	1.2	0.27
Subtotal 0-3	2.9	0.65
3-6	1.7	0.38
6-10	0.3	0.07
10-20	0	0
20+	0	0
SUBTOTAL 3+	2.0	0.45
TOTAL	4.9	1.10

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.6 in
4.06 cm

Average diameter, 3+fuels: 3.6 in
9.14 cm

Percent rotten, 3+fuels: 14 %

Volume of **sound** 3+fuels: 139 ft³/ac
9.7 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	130 yrs
PIPO	120 yrs

Average slope: 50 %
Aspect northwest
Elevation: 5490 ft 1673 m

Remarks

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: low
Torching: low
Crowning: low
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo
Ranger District Missoula
Drainage: W. Fk. Swartz Cr.

Photo taken. 6/20/77
By: W. C. Fischer

DATA SHEET

Stand No. 71

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 261, Douglas-fir/ninebark-ninebark phase (PSME/PHMA-PHMA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.5	0.11
0.25-1	1.9	0.43
1-3	2.1	0.47
Subtotal 0-3	4.5	1.01
3-6	0.8	0.18
6-10	0	0
10-20	0	0
20+	0	0
SUBTOTAL 3+	0.8	0.18
TOTAL	5.3	1.19

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 2.3 in

5.84 *cm*

Average diameter, 3+fuels: 3.3 in

8.38 *cm*

Percent rotten, 3+fuels: 67 %

Volume of **sound** 3+fuels: 21 ft^3/ac

1.5 *m^3/ha*

STAND AND SITE DATA

Age of overstory dominants:

PSME 75 yrs

LAOC 65 yrs

Average slope: 80 %

Aspect northeast

Elevation 3480 ft 1061 *m*

Remarks

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

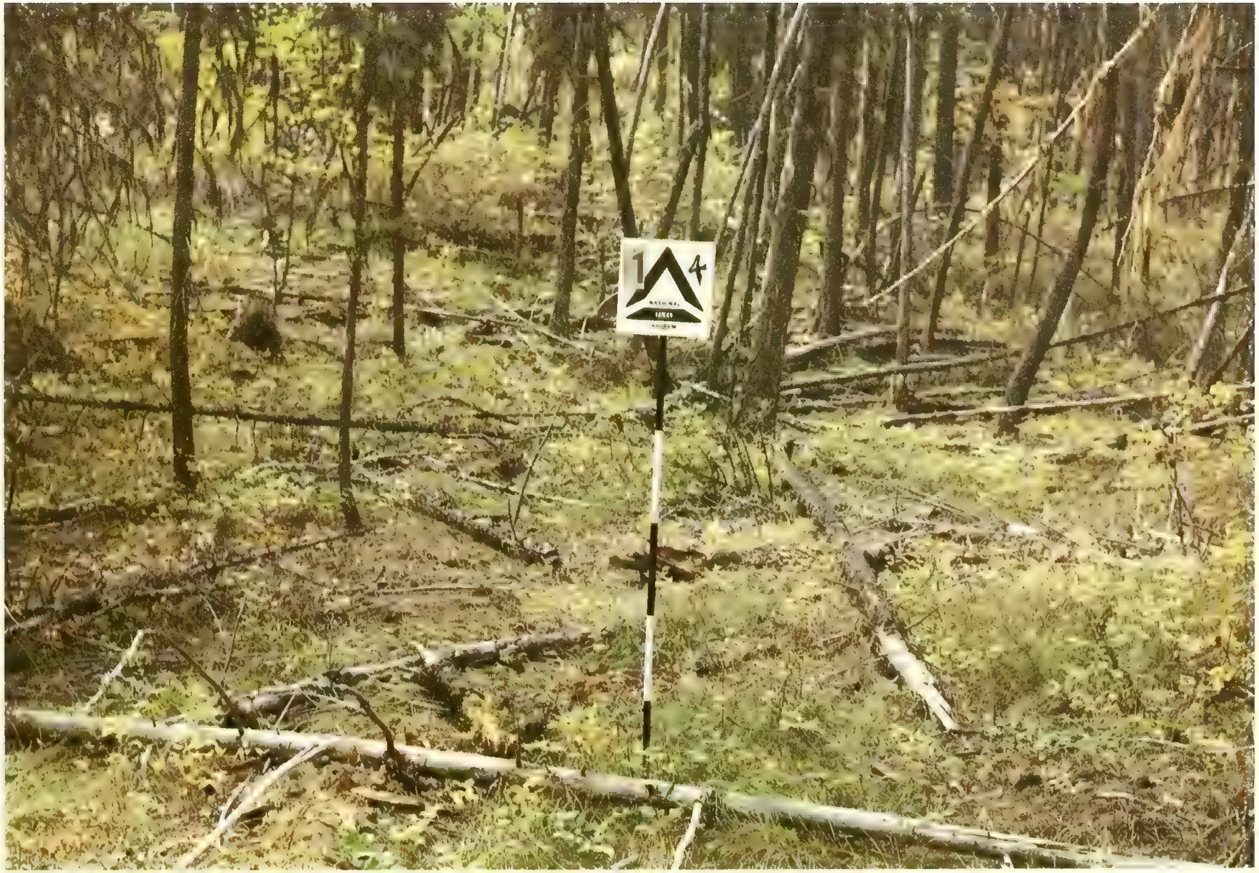
National Forest Lolo

Ranger District: Missoula

Drainage. Spring Cr.

Photo taken. 7/15/77

By. W. C. Fischer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DATA SHEET

Stand No. 14

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 261, Douglas-fir/ninebark-ninebark phase (PSME/PHMA-PHMA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.7	0.16
0.25-1	1.3	0.29
1-3	3.1	0.69
Subtotal 0-3	5.1	1.14
3-6	4.1	0.92
6-10	3.4	0.76
10-20	0	0
20+	0	0
SUBTOTAL 3+	7.5	1.68
TOTAL	12.6	2.82

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H/G	8/10

OTHER FUEL DATA

Average duff depth: 2.4 in
6.10 *cm*

Average diameter, 3+fuels: 4.3 in
10.92 *cm*

Percent rotten, 3+fuels: 58 %

Volume of **sound** 3+fuels: 250 ft³/ac
17.5 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:
PSME 80 yrs

Average slope: 2 %
Aspect: north
Elevation 3400 ft 1036 *m*

Remarks

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Ninemile

Drainage: Mill Cr.

Photo taken 9/22/76

By W. C. Fischer

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DATA SHEET

Stand No. 88

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 292, Douglas-fir/twinflower-pinegrass phase (PSME/LIBO-CARU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.2	0.04
0.25-1	1.5	0.34
1-3	4.0	0.90
Subtotal 0-3	5.7	1.28
3-6	5.2	1.17
6-10	2.5	0.56
10-20	0	0
20+	0	0
SUBTOTAL 3+	7.7	1.73
TOTAL	13.4	3.01

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
C	2

OTHER FUEL DATA

Average duff depth: 2.2 in
5.59 cm

Average diameter, 3+fuels: 4.1 in
10.41 cm

Percent rotten, 3+fuels: 25 %

Volume of **sound** 3+fuels:
462 ft³/ac
32.3 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
LAOC 285 yrs
PSME 246 yrs

Average slope: 23 %
Aspect northwest
Elevation 4430 ft 1366 m

Remarks: old seed-tree cut
Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: low

Torching: nil

Crowning: nil

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: N. Fk. Howard Cr.

Photo taken: 8/29/77

By W. C. Fischer

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DATA SHEET

Stand No. 13

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 521, Grand fir/queencup beadlily-queencup beadlily phase (ABGR/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	1.5	0.34
1-3	3.5	0.78
Subtotal 0-3	5.3	1.19
3-6	9.3	2.08
6-10	5.0	1.12
10-20	2.6	0.58
20+	0	0
SUBTOTAL 3+	16.9	3.78
TOTAL	22.2	4.97

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.8 in, 4.57 cm

Average diameter, 3+fuels: 4.7 in, 11.94 cm

Percent rotten, 3+fuels: 33 %

Volume of **sound** 3+fuels: 908 ft³/ac, 63.5 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	100 yrs
ABGR	50 yrs

Average slope: 10 %

Aspect: north

Elevation 3410 ft 1039 m

Remarks:

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90 ° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: low

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Ninemile

Drainage: Mill Cr.

Photo taken: 9/22/76

By W. C. Fischer

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Stand No. 9

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.1	0.02
0.25-1	1.0	0.22
1-3	4.0	0.90
Subtotal 0-3	5.1	1.14
3-6	4.5	1.01
6-10	5.1	1.14
10-20	8.7	1.95
20+	0	0
SUBTOTAL 3+	18.3	4.10
TOTAL	23.4	5.24

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
A	1

OTHER FUEL DATA

Average duff depth: 0.5 in
1.27 *cm*

Average diameter, 3+fuels:
5.6 in
14.22 *cm*

Percent rotten, 3+fuels: 7 %

Volume of **sound** 3+fuels:
1358 ft³/ac
95.0 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

Average slope: 29 %
Aspect: southwest
Elevation: 5720 ft 1744 *m*

Remarks: old clearcut and burn
Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: low
Torching: nil
Crowning: nil
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Cloudburst Cr.

Photo taken: 9/17/76
By: S. Cox

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DATA SHEET

Stand No. 89

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 292, Douglas-fir/twinflower-pinegrass phase (PSME/LIBO-CARU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.6	0.13
0.25-1	5.0	1.12
1-3	2.2	0.49
Subtotal 0-3	7.8	1.74
3-6	6.8	1.52
6-10	9.3	2.08
10-20	0	0
20+	0	0
SUBTOTAL 3+	16.1	3.60
TOTAL	23.9	5.34

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
K/G	11/10

OTHER FUEL DATA

Average duff depth: 1.6 in

4.06 cm

Average diameter, 3+fuels: 4.9 in

12.45 cm

Percent rotten, 3+fuels: 12 %

Volume of **sound** 3+fuels: 1134 ft³/ac

79.4 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME 105 yrs

Average slope: 54 %

Aspect: northwest

Elevation: 4240 ft 1292 m

Remarks: old partial cut

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: low

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: N. Fk. Howard Ck.

Photo taken: 8/29/77

By W. C. Fischer

DATA SHEET

Stand No. 5

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 661, Subalpine fir/twinflower-twinflower phase (ABLA/LIBO-LIBO)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.5	0.11
0.25-1	2.1	0.47
1-3	4.4	0.99
Subtotal 0-3	7.0	1.57
3-6	1.5	0.34
6-10	0	0
10-20	16.2	3.63
20+	0	0
SUBTOTAL 3+	17.7	3.97
TOTAL	24.7	5.54

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 3.2 in
8.13 cm

Average diameter, 3+fuels: 8.2 in
20.83 cm

Percent rotten, 3+fuels: 81 %

Volume of **sound** 3+fuels: 264 ft³/ac
18.5 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
LAOC 81 yrs
PICO 77 yrs

Average slope: 10 %
Aspect: west
Elevation 5095 ft 1553 m

Remarks: Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: low
Torching: medium
Crowning: low
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Cloudburst Ck.

Photo taken: 9/16/76
By: S. Cox

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DATA SHEET

Stand No. 29

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 283, Douglas-fir/blue huckleberry-beargrass phase (PSME/VAGL-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	1.7	0.38
1-3	1.9	0.43
Subtotal 0-3	3.9	0.88
3-6	5.9	1.32
6-10	14.9	3.34
10-20	1.3	0.29
20+	0	0
SUBTOTAL 3+	22.1	4.95
TOTAL	26.0	5.83

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.7 in
4.32 cm

Average diameter, 3+fuels: 5.4 in
13.72 cm

Percent rotten, 3+fuels: 47 %

Volume of **sound** 3+fuels: 932 ft³/ac
65.2 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

LAOC	130 yrs
PSME	115 yrs
PICO	105 yrs

Average slope: 40 %
Aspect: northwest
Elevation: 5425 ft 1654 m

Remarks:
Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: low
Torching: low
Crowning: low
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: W. Fk. Swartz Cr.

Photo taken: 6/20/77
By: W. C. Fischer

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DATA SHEET

Stand No. 30

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 261, Douglas-fir/ninebark-ninebark phase (PSME/PHMA-PHMA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	0.7	0.16
1-3	0.8	0.18
Subtotal 0-3	1.8	0.41
3-6	1.6	0.36
6-10	4.0	0.90
10-20	16.8	3.77
20+	3.1	0.69
SUBTOTAL 3+	25.5	5.72
TOTAL	27.3	6.13

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.5 in

3.81 cm

Average diameter, 3+fuels: 8.9 in

22.61 cm

Percent rotten, 3+fuels: 80 %

Volume of **sound** 3+fuels: 410 ft³/ac

28.7 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME 230 yrs

Average slope: 50 %

Aspect: northwest

Elevation: 5470 ft 1667 m

Remarks:

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90 ° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: W. Fk. Swartz Cr.

Photo taken: 6/20/77

By: W. C. Fischer

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DATA SHEET

Stand No. 56

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 203, Douglas-fir/blue huckleberry-beargrass phase (PSME/VAGL-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.4	0.09
0.25-1	2.7	0.61
1-3	3.5	0.78
Subtotal 0-3	6.6	1.48
3-6	11.7	2.62
6-10	4.0	0.90
10-20	7.4	1.66
20+	0	0
SUBTOTAL 3+	23.1	5.18
TOTAL	29.7	6.66

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.9 in
4.83 cm

Average diameter, 3+fuels: 4.9 in
12.45 cm

Percent rotten, 3+fuels: 52 %

Volume of **sound** 3+fuels: 897 ft³/ac
62.8 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO	42 yrs
PSME	30 yrs
LAOC	30 yrs

Average slope: 60 %
Aspect northeast
Elevation: 5470 ft 1667 m

Remarks: old thinning slash
Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: medium
Crowning: low
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Swartz Cr.

Photo taken: 7/6/77
By: W. C. Fischer

DATA SHEET

Stand No. 33

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.5	0.11
0.25-1	2.9	0.65
1-3	12.9	2.89
Subtotal 0-3	16.3	3.65
3-6	13.0	2.91
6-10	2.2	0.49
10-20	5.4	1.21
20+	0	0
SUBTOTAL 3+	20.6	4.61
TOTAL	36.9	8.26

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.5 in
6.35 cm

Average diameter, 3+fuels: 4.2 in
10.67 cm

Percent rotten, 3+fuels: 35 %

Volume of **sound** 3+fuels: 1070 ft³/ac
74.9 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

LAOC	134 yrs
PICO	120 yrs
PSME	90 yrs

Average slope 50 %
Aspect east
Elevation 5555 ft 1693 m

Remarks
Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: high
Intensity: high
Torching: medium
Crowning: medium
Resistance to control: high

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: W. Fk. Swartz Cr.

Photo taken: 6/20/77
By W. C. Fischer

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DATA SHEET

Stand No. 91

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 691, Douglas-fir/blue huckleberry-beargrass phase (PSME/VAGL-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.7	0.16
0.25-1	2.9	0.65
1-3	6.7	1.50
Subtotal 0-3	10.3	2.31
3-6	23.2	5.20
6-10	4.7	1.05
10-20	0	0
20+	0	0
SUBTOTAL 3+	27.9	6.25
TOTAL	38.2	8.56

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
I	13

OTHER FUEL DATA

Average duff depth: 1.3 in
3.3 cm

Average diameter, 3+fuels: 4.0 in
10.16 cm

Percent rotten, 3+fuels: 1 %

Volume of **sound** 3+fuels: 2216 ft³/ac
155.1 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

LAOC	70 yrs
PSME	62 yrs
PICO	60 yrs

Average slope: 30 %
Aspect: northwest
Elevation: 5270 ft 1606 m

Remarks: old thinning slash
Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: high
Intensity: high
Torching: low
Crowning: low
Resistance to control: medium

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Howard Cr.

Photo taken: 8/29/77
By W. C. Fischer

DATA SHEET

Stand No. 7

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.5	0.11
0.25-1	2.1	0.47
1-3	6.5	1.46
Subtotal 0-3	9.1	2.04
3-6	18.2	4.08
6-10	3.9	0.87
10-20	0	0
20+	28.1	6.30
SUBTOTAL 3+	50.2	11.25
TOTAL	59.3	13.29

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.1 in
5.33 cm

Average diameter, 3+fuels: 4.7 in
11.94 cm

Percent rotten, 3+fuels: 0 %

Volume of **sound** 3+fuels: 4023 ft³/ac
281.5 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO	87 yrs
LAOC	80 yrs
ABLA	70 yrs

Average slope 10 %
Aspect west
Elevation 5415 ft 1651 m

Remarks old thinning slash - dozer trampled

Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: low
Crowning: low
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Cloudburst Cr.

Photo taken: 9/17/76
By: S. Cox

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2

DATA SHEET

Stand No. 32

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 261, Douglas-fir/ninebark-ninebark phase (PSME/PHMA-PHMA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	1.5	0.34
0.25-1	4.4	0.99
1-3	10.3	2.31
Subtotal 0-3	16.2	3.64
3-6	20.8	4.66
6-10	27.1	6.08
10-20	0	0
20+	0	0
SUBTOTAL 3+	47.9	10.74
TOTAL	64.1	14.38

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
I	13

OTHER FUEL DATA

Average duff depth: 1.4 in
3.56 cm

Average diameter, 3+fuels: 4.9 in
12.45 cm

Percent rotten, 3+fuels: 4 %

Volume of **sound** 3+fuels: 3673 ft³/ac
257.0 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

LAOC	150 yrs
PSME	140 yrs
PICO	130 yrs

Average slope: 60 %
Aspect: east
Elevation: 5525 ft 1684 m

Remarks: recent thinning slash in
old clearcut
Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: high
Intensity: high
Torching: medium
Crowning: medium
Resistance to control: medium

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: W. Fk. Swartz Cr.

Photo taken: 6/20/77
By W. C. Fischer

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DATA SHEET

Stand No. 8

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	1.5	0.34
0.25-1	3.1	0.69
1-3	11.0	2.47
Subtotal 0-3	15.6	3.50
3-6	34.8	7.80
6-10	20.5	4.60
10-20	0.6	0.13
20+	0	0
SUBTOTAL 3+	55.9	12.53
TOTAL	71.5	16.03

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
I	13

OTHER FUEL DATA

Average duff depth: 4.6 in 11.68 cm

Average diameter, 3+fuels: 4.7 in 11.94 cm

Percent rotten, 3+fuels: 9 %

Volume of **sound** 3+fuels: 5024 ft³/ac 351.5 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO	87 yrs
LAOC	80 yrs
ABLA	70 yrs

Average slope. 40 %

Aspect north

Elevation 5720 ft 1744 m

Remarks: old thinning slash

Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: high

Intensity: high

Torching: medium

Crowning: low

Resistance to control: high

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Cloudburst Cr.

Photo taken: 9/17/76

By S. Cox

2
8

DATA SHEET

Stand No. 28

FOREST COVER TYPE: SAF NO. 212, Larch - Douglas-fir

MONTANA HABITAT TYPE: NO. 283, Douglas-fir/blue huckleberry-beargrass phase (PSME/VAGL-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.3	0.07
0.25-1	1.5	0.34
1-3	4.3	0.96
Subtotal 0-3	6.1	1.37
3-6	12.2	2.73
6-10	17.0	3.81
10-20	2.0	0.45
20+	36.6	8.20
SUBTOTAL 3+	67.8	15.19
TOTAL	73.9	16.56

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.7 in

6.86 *cm*

Average diameter, 3+fuels: 5.6 in

14.22 *cm*

Percent rotten, 3+fuels: 21 %

Volume of **sound** 3+fuels: 4304 ft³/ac

301.2 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PSME	110 yrs
PICO	95 yrs

Average slope: 30 %

Aspect northwest

Elevation: 5500 ft 1676 *m*

Remarks: Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: medium

Torching: low

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: W. Fk. Swartz Cr.

Photo taken: 6/20/77

By: W. C. Fischer

SERIES 4

INTERIOR DOUGLAS-FIR

SAF COVER TYPE 210

4
3

DATA SHEET

Stand No. 43

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 283, Douglas-fir/blue huckleberry-beargrass phase (PSME/VAGL-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.4	0.09
0.25-1	1.2	0.27
1-3	0.8	0.18
Subtotal 0-3	2.4	0.54
3-6	0.5	0.11
6-10	0	0
10-20	0	0
20+	0	0
SUBTOTAL 3+	0.5	0.11
TOTAL	2.9	0.65

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.4 in, 3.56 *cm*

Average diameter, 3+fuels: 4.3 in, 10.92 *cm*

Percent rotten, 3+fuels: 0 %

Volume of **sound** 3+fuels: 37 ft³/ac, 2.6 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PICO	100 yrs
PSME	84 yrs

Average slope: 57 %

Aspect: southeast

Elevation: 6145 ft 1873 *m*

Remarks

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Gilbert Cr.

Photo taken: 6/23/77

By: W. C. Fischer

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DATA SHEET

Stand No. 14A

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 261, Douglas-fir/ninebark-ninebark phase (PSME/PHMA-PHMA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.9	0.20
0.25-1	1.8	0.40
1-3	1.2	0.27
Subtotal 0-3	3.9	0.87
3-6	0.3	0.07
6-10	0.3	0.07
10-20	0	0
20+	0	0
SUBTOTAL 3+	0.6	0.14
TOTAL	4.5	1.01

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 2.0 in
5.08 cm

Average diameter, 3+fuels: 4.3 in
10.92 cm

Percent rotten, 3+fuels: 65 %

Volume of **sound** 3+fuels: 17 ft³/ac
1.2 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
PIPO 67 yrs
PSME 60 yrs

Average slope: 22 %
Aspect south
Elevation 3200 ft 975 m

Remarks
Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Kootenai

Ranger District: Troy

Drainage: Camp Cr.

Photo taken 6/28/78

By W. C. Fischer

DATA SHEET

Stand No. 39A

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 312, Douglas-fir/snowberry-pinegrass phase (PSME/SYAL-CARU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.4	0.09
0.25-1	0.7	0.16
1-3	1.3	0.29
Subtotal 0-3	2.4	0.54
3-6	1.4	0.31
6-10	2.5	0.56
10-20	0	0
20+	0	0
SUBTOTAL 3+	3.9	0.87
TOTAL	6.3	1.41

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.4 in; 3.56 cm

Average diameter, 3+ fuels: 4.8 in; 12.19 cm

Percent rotten, 3+ fuels: 98 %

Volume of **sound** 3+ fuels: 7 ft³/ac; 0.5 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
PSME 75 yrs

Average slope: 13 %
Aspect southwest
Elevation 6330 ft 1929 m

Remarks
Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90 ° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lewis & Clark

Ranger District: White Sulphur Springs

Drainage: Whitetail Deer Cr.

Photo taken: 8/15/78

By W. C. Fischer

DATA SHEET

Stand No. 41A

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 220, Douglas-fir/Idaho fescue (PSME/FEID)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.5	0.11
0.25-1	1.5	0.34
1-3	0.8	0.18
Subtotal 0-3	2.8	0.63
3-6	0.6	0.13
6-10	1.8	0.40
10-20	1.4	0.31
20+	0	0
SUBTOTAL 3+	3.8	0.84
TOTAL	6.6	1.47

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 0.9 in

2.29 cm

Average diameter, 3+fuels:

5.8 in

14.73 cm

Percent rotten, 3+fuels: 25 %

Volume of **sound** 3+fuels:

228 ft³/ac

16.0 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME 103 yrs

Average slope 9 %

Aspect southeast

Elevation: 6985 ft 2129 m

Remarks

Fire Ecology Group Five

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: nil

Crowning: nil

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lewis & Clark

Ranger District: White Sulphur Springs

Drainage: Spring Cr.

Photo taken: 8/15/78

By W. C. Fischer

DATA SHEET

Stand No. 49

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 323, Douglas-fir/pinegrass-pinegrass phase (PSME/CARU-CARU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.4	0.09
0.25-1	0.9	0.20
1-3	1.2	0.27
Subtotal 0-3	2.5	0.56
3-6	0.6	0.13
6-10	1.0	0.22
10-20	3.7	0.83
20+	0	0
SUBTOTAL 3+	5.3	1.18
TOTAL	7.8	1.74

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
C/H	2/8

OTHER FUEL DATA

Average duff depth: 1.0 in
2.54 cm

Average diameter, 3+fuels: 7.3 in
18.54 cm

Percent rotten, 3+fuels: 71 %

Volume of **sound** 3+fuels: 120 ft³/ac
8.4 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
PSME 295 yrs
PIPO 150 yrs

Average slope: 70 %
Aspect: northwest
Elevation 5800 ft 1768 m

Remarks

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Gilbert Cr.

Photo taken 6/24/77

By W. C. Fischer

2 8

DATA SHEET

Stand No. 28A

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 323, Douglas-fir/pinegrass-pinegrass phase (PSME/CARU-CARU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.4	0.09
0.25-1	1.1	0.25
1-3	3.6	0.81
Subtotal 0-3	5.1	1.15
3-6	2.0	0.45
6-10	0.8	0.18
10-20	0.4	0.09
20+	0	0
SUBTOTAL 3+	3.2	0.72
TOTAL	8.3	1.87

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H/G	8/10

OTHER FUEL DATA

Average duff depth: 2.4 in, 6.10 cm

Average diameter, 3+fuels: 3.9 in, 9.91 cm

Percent rotten, 3+fuels: 41 %

Volume of **sound** 3+fuels: 151 ft^3/ac, 10.6 m^3/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO	77 yrs
PSME	70 yrs

Average slope: 14 %

Aspect: northeast

Elevation: 5250 ft 1600 m

Remarks: Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: high

Intensity: medium

Torching: low

Crowning: medium

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Helena

Ranger District: Lincoln

Drainage: Keep Cool Cr.

Photo taken: 7/28/78

By W. C. Fischer

3
6

DATA SHEET

Stand No. 36A

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 292, Douglas-fir/twinflower-pinegrass phase (PSME/LIBO-CARU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.5	0.11
0.25-1	1.5	0.34
1-3	4.2	0.94
Subtotal 0-3	6.2	1.39
3-6	2.3	0.52
6-10	1.9	0.43
10-20	0	0
20+	0	0
SUBTOTAL 3+	4.2	0.95
TOTAL	10.4	2.34

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.8 in

7.11 cm

Average diameter, 3+fuels: 4.2 in

10.67 cm

Percent rotten, 3+fuels: 76 %

Volume of **sound** 3+fuels: 78 ft³/ac

5.5 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	109 yrs
PICO	106 yrs
PICEA	86 yrs

Average slope: 16 %

Aspect: northwest

Elevation: 6050 ft 1844 m

Remarks:

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: medium

Resistance to control: low

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lewis & Clark

Ranger District: White Sulphur Springs

Drainage: Fourmile Cr.

Photo taken: 8/10/78

By: W. C. Fischer

DATA SHEET

Stand No. 27A

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 283, Douglas-fir/blue huckleberry-beargrass phase (PSME/VAGL-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.2	0.04
0.25-1	0.8	0.18
1-3	1.2	0.27
Subtotal 0-3	2.2	0.49
3-6	1.9	0.43
6-10	5.2	1.17
10-20	1.7	0.38
20+	0	0
SUBTOTAL 3+	8.8	1.98
TOTAL	11.0	2.47

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.9 in, 4.83 cm

Average diameter, 3+fuels: 5.6 in, 14.22 cm

Percent rotten, 3+fuels: 92 %

Volume of **sound** 3+fuels: 55 ft³/ac, 3.9 m³/ha

STAND AND SITE DATA

Age of overstory dominants: PSME 86 yrs

Average slope: 17 %

Aspect: northwest

Elevation: 5120 ft 1561 m

Remarks: Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential: MEDIUM

STAND LOCATION

National Forest: Helena

Ranger District: Lincoln

Drainage: Keep Cool Cr.

Photo taken: 7/28/78

By: W. C. Fischer

1
2

DATA SHEET

Stand No. 12A

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 521, Grand fir/queencup beadlily-queencup beadlily phase (ABGR/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	1.1	0.25
1-3	0.4	0.09
Subtotal 0-3	1.8	0.41
3-6	1.1	0.25
6-10	6.4	1.43
10-20	3.5	0.78
20+	0	0
SUBTOTAL 3+	11.0	2.46
TOTAL	12.8	2.87

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 2.7 in

6.86 cm

Average diameter, 3+fuels: 6.8 in

17.27 cm

Percent rotten, 3+fuels: 83 %

Volume of **sound** 3+fuels: 154 ft³/ac

10.8 m³/ha

STAND AND SITE DATA

Age of overstory dominants.

PIMO	112 yrs
PSME	107 yrs
PIPO	80 yrs
ABGR	80 yrs

Average slope 10 %

Aspect southwest

Elevation 3100 ft 945 m

Remarks

Fire Ecology Group Eleven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: low

Crowning: nil

Resistance to control: medium

Overall Fire Potential LOW

STAND LOCATION

National Forest. Kootenai

Ranger District Libby

Drainage Quartz Cr.

Photo taken 6/27/78

By W. C. Fischer

3
1

DATA SHEET

Stand No. 37A

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 350, Douglas-fir/kinnikinnick (PSME/ARUV)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	1.9	0.43
1-3	2.9	0.65
Subtotal 0-3	5.1	1.15
3-6	2.3	0.52
6-10	2.5	0.56
10-20	3.3	0.74
20+	0	0
SUBTOTAL 3+	8.1	1.82
TOTAL	13.2	2.97

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H/G	8/10

OTHER FUEL DATA

Average duff depth: 1.1 in
2.79 cm

Average diameter, 3 + fuels: 5.0 in
12.70 cm

Percent rotten, 3 + fuels: 46 %

Volume of **sound** 3 + fuels: 350 ft³/ac
24.5 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	112 yrs
PIPO	68 yrs

Average slope: 6 %
Aspect: southeast
Elevation: 6130 ft 1868 m

Remarks: Fire Ecology Group Four

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: low
Crowning: low
Resistance to control: low

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lewis & Clark
Ranger District: White Sulphur Springs
Drainage: Decker Cr.

Photo taken: 8/10/78
By W. C. Fischer

DATA SHEET

Stand No. 42A

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 323, Douglas-fir/pinegrass-pinegrass phase (PSME/CARU-CARU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.5	0.11
0.25-1	1.0	0.22
1-3	0.8	0.18
Subtotal 0-3	2.5	0.51
3-6	1.7	0.38
6-10	6.2	1.39
10-20	3.1	0.69
20+	0	0
SUBTOTAL 3+	11.0	2.46
TOTAL	13.5	2.97

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 2.1 in 5.33 cm

Average diameter, 3+fuels: 6.3 in 16.00 cm

Percent rotten, 3+fuels: 93 %

Volume of **sound** 3+fuels: 67 ft³/ac 4.7 m³/ha

STAND AND SITE DATA

Age of overstory dominants.
PSME 82 yrs

Average slope 8 %
Aspect southeast
Elevation: 6500 ft 1981 m

Remarks

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: low

Crowning: medium

Resistance to control: low

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lewis & Clark

Ranger District: White Sulphur Springs

Drainage. Miller Gulch

Photo taken: 8/15/78

By W. C. Fischer

3
8

DATA SHEET

Stand No. 38A

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 323, Douglas-fir/pinegrass-pinegrass phase (PSME/CARU-CARU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.4	0.09
0.25-1	2.4	0.54
1-3	5.0	1.12
Subtotal 0-3	7.8	1.75
3-6	3.4	0.76
6-10	2.6	0.58
10-20	2.0	0.45
20+	0	0
SUBTOTAL 3+	8.0	1.79
TOTAL	15.8	3.54

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.0 in
5.08 cm

Average diameter, 3+fuels:
4.6 in
11.68 cm

Percent rotten, 3+fuels: 73 %

Volume of **sound** 3+fuels:
172 ft³/ac
12.0 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
PSME 104 yrs

Average slope 6 %
Aspect: northwest
Elevation: 6300 ft 1920 m

Remarks:
Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: medium
Crowning: low
Resistance to control: low

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lewis & Clark
Ranger District: White Sulphur Springs
Drainage: Decker Cr.

Photo taken: 8/10/78
By W. C. Fischer

3
6

DATA SHEET

Stand No. 86

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 261, Douglas-fir/ninebark-ninebark phase (PSME/PHMA-PHMA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.8	0.18
0.25-1	1.8	0.40
1-3	3.7	0.83
Subtotal 0-3	6.3	1.41
3-6	0.4	0.09
6-10	7.5	1.68
10-20	2.0	0.45
20+	0	0
SUBTOTAL 3+	9.9	2.22
TOTAL	16.2	3.63

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.4 in

6.10 cm

Average diameter, 3+fuels: 7.6 in

19.30 cm

Percent rotten, 3+fuels: 99 %

Volume of **sound** 3+fuels: 10 ft³/ac

0.7 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
PSME 65 yrs

Average slope: 38 %
Aspect south
Elevation 5310 ft 1618 m

Remarks

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: medium

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Howard Cr.

Photo taken: 8/22/77

By W. C. Fischer

DATA SHEET

Stand No. 43A

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 312, Douglas-fir/snowberry-pinegrass phase (PSME/SYAL-CARU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.5	0.11
0.25-1	2.7	0.61
1-3	8.7	1.95
Subtotal 0-3	11.9	2.67
3-6	3.6	0.81
6-10	1.8	0.40
10-20	0	0
20+	0	0
SUBTOTAL 3+	5.4	1.21
TOTAL	17.3	3.88

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.7 in
6.86 cm

Average diameter, 3+fuels: 4.0 in
10.16 cm

Percent rotten, 3+fuels: 62 %

Volume of **sound** 3+fuels: 162 ft³/ac
11.3 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	92 yrs
PICO	84 yrs

Average slope: 6 %
Aspect southeast
Elevation 6450 ft 1966 m

Remarks:
Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: high
Crowning: medium
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lewis & Clark
Ranger District: White Sulphur Springs
Drainage: Miller Gulch

Photo taken: 8/15/78
By: W. C. Fischer

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4

DATA SHEET

Stand No. 34

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 262, Douglas-fir/ninebark-pinegrass (PSME/PHMA-CARU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	2.3	0.52
1-3	2.5	0.56
Subtotal 0-3	5.1	1.15
3-6	7.0	1.57
6-10	7.7	1.73
10-20	0	0
20+	0	0
SUBTOTAL 3+	14.7	3.30
TOTAL	19.8	4.45

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 0.3 in
0.76 cm

Average diameter, 3+fuels: 4.8 in
12.19 cm

Percent rotten, 3+fuels: 3 %

Volume of **sound** 3+fuels: 1146 ft³/ac
80.2 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

Average slope: 60 %
Aspect: northwest
Elevation: 5530 ft 1686 m

Remarks: old burn

Fire Ecology Group Four

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: nil
Crowning: nil
Resistance to control: low

Overall Fire Potential: LOW

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: W. Fk. Swartz Cr.

Photo taken: 6/20/77
By: W. C. Fischer

4 0

DATA SHEET

Stand No. 40A

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 350, Douglas-fir/kinnikinnick (PSME/ARUV)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.4	0.09
0.25-1	1.9	0.43
1-3	6.0	1.35
Subtotal 0-3	8.3	1.87
3-6	7.7	1.73
6-10	2.6	0.58
10-20	7.0	1.57
20+	0	0
SUBTOTAL 3+	17.3	3.88
TOTAL	25.6	5.75

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 3.0 in
7.62 cm

Average diameter, 3+fuels: 4.8 in
12.19 cm

Percent rotten, 3+fuels: 65 %

Volume of **sound** 3+fuels: 507 ft³/ac
35.5 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	105 yrs
PICO	88 yrs

Average slope: 11 %
Aspect: northwest
Elevation: 6320 ft 1926 m

Remarks

Fire Ecology Group Four

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: high

Intensity: high

Torching: high

Crowning: medium

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lewis & Clark

Ranger District: White Sulphur Springs

Drainage: Whitetail Deer

Photo taken: 8/15/78

By W. C. Fischer

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2

DATA SHEET

Stand No. 42

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.4	0.09
0.25-1	1.9	0.43
1-3	2.5	0.56
Subtotal 0-3	4.8	1.08
3-6	1.6	0.36
6-10	2.9	0.65
10-20	5.4	1.21
20+	11.9	2.67
SUBTOTAL 3+	21.8	4.89
TOTAL	26.6	5.97

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.1 in
2.79 cm

Average diameter, 3+fuels: 8.3 in
21.08 cm

Percent rotten, 3+fuels: 17 %

Volume of **sound** 3+fuels: 1441 ft³/ac
100.8 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	355 yrs
PICO	150 yrs
ABLA	76 yrs

Average slope: 55 %
Aspect: southeast
Elevation: 5990 ft 1826 m

Remarks: Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: low
Crowning: low
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Gilbert Cr.

Photo taken: 6/23/77
By W. C. Fischer

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8

DATA SHEET

Stand No. 48

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 283, Douglas-fir/blue huckleberry-beargrass phase (PSME/VAGL-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.2	0.04
0.25-1	1.1	0.25
1-3	1.9	0.43
Subtotal 0-3	3.2	0.72
3-6	3.3	0.74
6-10	14.6	3.27
10-20	17.4	3.90
20+	3.5	0.78
SUBTOTAL 3+	38.8	8.69
TOTAL	42.0	9.41

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.2 in
3.05 cm

Average diameter, 3+fuels: 7.4 in
18.80 cm

Percent rotten, 3+fuels: 90 %

Volume of **sound** 3+fuels: 326 ft³/ac
22.8 m³/ha

STAND AND SITE DATA

Age of overstory dominants.

PIPO	335 yrs
PSME	186 yrs
PICO	62 yrs

Average slope 40 %
Aspect: northwest
Elevation 5870 ft 1789 m

Remarks:

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: medium
Torching: medium
Crowning: low
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Gilbert Cr.

Photo taken: 6/24/77
By W. C. Fischer

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Stand No. 95

FOREST COVER TYPE: SAF NO. 210, Interior Douglas-fir

MONTANA HABITAT TYPE: NO. 292, Douglas-fir/twinflower-pinegrass phase (PSME/LIBO-CARU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.5	0.11
0.25-1	1.8	0.40
1-3	5.0	1.12
Subtotal 0-3	7.3	1.63
3-6	10.3	2.31
6-10	25.6	5.74
10-20	9.7	2.17
20+	0	0
SUBTOTAL 3+	45.6	10.22
TOTAL	52.9	11.85

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.2 in

5.59 cm

Average diameter, 3+ fuels:

6.1 in

15.49 cm

Percent rotten, 3+ fuels: 76 %

Volume of **sound** 3+ fuels:

870 ft³/ac

60.9 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	145 yrs
PICO	118 yrs

Average slope: 10 %

Aspect northeast

Elevation 5550 ft 1692 m

Remarks

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest Lolo

Ranger District Missoula

Drainage: Gillispie Cr.

Photo taken 6/13/78

By W. C. Fischer

☆ U.S. GOVERNMENT PRINTING OFFICE: 1981-0-781-749

Fischer, William C.
1981. Photo guide for appraising downed woody fuels in Montana forests: Interior ponderosa pine, ponderosa pine - larch - Douglas-fir, larch - Douglas-fir, and interior Douglas-fir cover types. USDA For. Serv. Gen. Tech. Rep. INT-97, 133 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Four series of color photographs show different levels of downed woody material resulting from natural processes in four forest cover types in Montana. Each photo is supplemented by fuel inventory data and potential fire behavior ratings.

KEYWORDS: forest fuels, fire behavior, fire hazard, fuel appraisal

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

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Provo, Utah (in cooperation with Brigham Young University)

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NOVEMBER 1981

PHOTO GUIDE FOR APPRAISING DOWNED WOODY FUELS IN MONTANA FORESTS:

Lodgepole Pine, and Engelmann Spruce–Subalpine Fir Cover Types

William C. Fischer

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OGDEN, UTAH 84401

THE AUTHOR

WILLIAM C. FISCHER is a research forester for the Fire Effects and Use Research and Development Program, at the Northern Forest Fire Laboratory. His current assignment is to develop techniques and procedures for applying existing research knowledge to the task of producing improved operational fire management plans, with special emphasis on fire use, fuel treatment, and fuel management plans. Mr. Fischer received his bachelor's degree in forestry from the University of Michigan in 1956. From 1956 to 1966, he did Ranger District and forest staff work in timber management and fire control on the Boise National Forest.

RESEARCH SUMMARY

Two series of color photographs show different levels of downed woody material resulting from natural processes in two forest cover types in Montana. Each photo is supplemented by inventory data describing the size, weight, volume, and condition of the debris pictured. A subjective evaluation of potential fire behavior under an average bad fire weather situation is given.

Instructions are provided for using the photos to describe fuels and to evaluate potential fire hazard.

GENERAL TECHNICAL REPORT INT-98
NOVEMBER 1981

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ACKNOWLEDGMENTS

The fire behavior potential ratings assigned to the photos in this guide are the result of on-site evaluation by the following fire managers and researchers:

Donald E. Abbott, Deerlodge National Forest
George F. Bissonette, Kootenai National Forest
Dr. James K. Brown, Northern Forest Fire Laboratory
Fred L. Cavill, Lolo National Forest
Farrell G. Cooper, Lolo National Forest
Ronald G. Curtiss, Kootenai National Forest
Walter L. De Zell, Bitterroot National Forest
John B. Dillon, Kootenai National Forest
Wyatt W. Frost, Bitterroot National Forest
Horace F. Goodwin, Custer National Forest
Del Goss, Helena National Forest
Patrick F. Hartless, Northern Forest Fire Laboratory
Roger O. Hearst, Lolo National Forest
Jerry A. Hinman, Bitterroot National Forest
Robert Kellogg, Helena National Forest
Douglas H. Mackay, Lewis and Clark National Forest
Jerrald W. Miller, Lolo National Forest
Robert W. Mutch, Lolo National Forest
Dr. Rodney A. Norum, Northern Forest Fire Laboratory[1]
John V. Puckett, Northern Region Aviation and Fire Management
Delmar L. Radtke, Northern Region Timber Management
Charles E. Rodgers, Lolo National Forest
Everett Stiger, Helena National Forest
Russell H. Trostad, Lewis and Clark National Forest
Walter J. Tomascak, Custer National Forest
Don V. Williams, Northern Region Aviation and Fire Management (Retired)
Jerry Williams, Montana State Division of Forestry

The author gratefully acknowledges the help received from these men and thanks them for their willingness to share their expertise. Nonan V. Noste, Northern Forest Fire Laboratory, conducted many of the fire behavior potential rating sessions. His help is also gratefully acknowledged.

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[1] Subsequently assigned to Institute of Northern Forestry, Fairbanks, Alaska.

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unscheduled prescribed fires

PURPOSE OF PHOTO SERIES

This photo guide contains information that can be used to appraise the dead woody debris on the forest floor of lodgepole pine and Engelmann spruce - subalpine fir forest cover types (SAF 1954) in Montana. The guide is primarily for natural (nonslash) fuels, although some photos include old logging and thinning slash. Natural fuels result from wind, snow, and mechanical breakage, natural pruning of lower branches, needle fall, windthrow, blowdown, and the falling of trees killed by insects, disease, fire, and competition for light and moisture. The old logging and thinning slash shown has either been treated or left untreated. It can therefore be considered a part of the natural fuel complex.

This guide is designed to help forest managers describe the deadwood on the forest floor, to estimate the amount of such material, and to evaluate its fire hazard. The photos show a variety of fuel situations that exist in lodgepole pine and spruce- fir forests in Montana and surrounding Northern Rocky Mountain areas.

The fuel appraisal obtained from this guide can be used to plan fire management strategies including fire prevention, fuel treatment, prescribed fire, dispatching for fire suppression, and establishing criteria for unscheduled prescribed fires.

The photos provide a relatively quick and inexpensive aid for accomplishing fuel appraisal over large forested areas. Although the precision of this procedure is unknown, it is expected to be intermediate: less than standard fuel inventory but greater than designating a stylized fuel model such as used in the National Fire Danger Rating System.

Perhaps the strongest feature of this series is the fire potential rating with each photo. Alternative methods for evaluating fire potential are generally unavailable, and those methods that do exist are outdated or not well suited for rating nonuniform fuel situations.

USING THE PHOTOS

Arranging the Photos

The photos and accompanying data sheets are presented in two series:

Series 1—Lodgepole pine cover type.

Series 2—Engelmann spruce - subalpine fir cover type.

Within each series, the photos are arranged according to total fuel loading. The first photo in each series shows the lightest fuel load, the last shows the heaviest load.

The Data Sheet

The fuel complex shown in each photo is described on an accompanying data sheet in terms of the following characteristics:

1. Forest cover type.
2. Montana habitat type.
3. Stand and site data: age of overstory dominants, average slope, aspect, elevation, and fire ecology group.
4. Down and dead woody fuel loadings by size class.
5. Other fuel data: average duff depth and for fuels 3 inches (7.62 cm) in diameter and greater, the average diameter, the percent rotten, and the volume of sound material.
6. National Fire Danger Rating System fuel model.
7. Stylized fuel model.

Symbols used for forest vegetation are the standard symbols for Northern Region plants (USDA Forest Service 1969). The symbols represent the first two letters of the generic name and the first two letters of the specific name of the plant species (such as PICO - *Pinus contorta*).

Describing the Fuel Complex

Several important fuel characteristics can be seen in each photo: (1) The amount of fuel in the different diameter classes, (2) the general condition of the fuel (sound versus rotten), (3) the distribution of the fuel over the area, and (4) the depth of the fuel (each black and white section on the plot marker is 1 foot [0.3048 m]). Consequently, the manager can use the photos to estimate values for these characteristics of woody debris on the forest floor.

To use the photos to describe downed woody fuels, simply inspect the fuel complex and then select the photo that most nearly compares with what is on the ground. Then use the information on the data sheet to describe the observed fuel complex.

Perhaps no one photo adequately represents the actual situation. If this is the case, select two photos that bracket the observed fuel complex and then interpolate between the values on the data sheets accompanying the selected photos.

Rather than trying to select one photo or a pair of photos that best reflects the entire fuel complex, the user could describe each of the above-mentioned fuel characteristics separately. This could be done by using the following procedure suggested by Maxwell and Ward (1976a, 1976b), as adapted by Koski and Fischer (1979):

1. Observe each of the characteristics of the fuel complex on the ground.
2. For each characteristic, select the photo that most nearly matches, or photos that bracket the observed situations.
3. For each characteristic, obtain a value from the data sheet accompanying the selected photo (or interpolate a value if a pair of photos was selected).

The above procedure should only be used when a single photo or a pair of photos can't be used to describe the observed situation. For most fuel situations, any improvement in estimates obtained by rating each fuel characteristic separately is not justified by the increased time it takes to get them.

These procedures refer to use of the photos at a specific point. This can be a representative point and the results applied to an entire forest stand. This method is satisfactory when the fuels are uniform throughout the stand. It will be difficult to select a representative point in many stands. The photos can be used to sample stands when nonuniform fuels preclude the selection of a representative point. The procedure is as follows:

1. Establish 10 or more points, spread systemically through the stand.
2. At each point evaluate the fuels within clear eyesight.
3. Summarize the results as a simple average for the stand or express the results as the percent of area in several classes (for example, 40 percent of stand >10 tons/acre, 60 percent of stand <30 tons/acre).

Rating Fire Potential

The data sheet for each photo contains adjective ratings for five different expressions of fire behavior: rate of spread, intensity, torching, crowning, and resistance to control. An overall fire behavior potential rating is also given for the fuel complex pictured. The ratings are for an "average bad" fire weather situation defined as: 80° -90° F temperature (27° -32° C), 15-20 percent relative humidity, 10-15 mi/h windspeed (16-24 km/h), and 4 weeks since a significant rain (0.10 inch [0.25 cm] or greater).

This approach to estimating fire potential is not without precedent in the Northern Rocky Mountains. In many ways it is a refinement of the time-tested concept of fuel rating introduced more than 40 years ago by L. G. Hornby (1936).

The adjective ratings nil, low, medium, high, and extreme are defined as follows for each of the different expressions of fire behavior:

Rate of Spread

Nil—fire cannot sustain itself.

Low—spread will be slow and discontinuous.

Medium—uniform spread possible, but can be stopped by aggressive ground attack with hand tools.

High—spread will be rapid; indirect attack on fire front may be required for control.

Extreme—spread will be explosive; little chance of control until weather changes.

Intensity

Nil—fire cannot sustain itself.

Low—cool fire; very little hot spotting required for control.

Medium—fire will burn hot in places; aggressive hot spotting with hand tools likely to be successful.

High—too hot for sustained direct attack with hand tools; aerial tankers or large ground tanker required to cool fire front.

Extreme—direct ground attack not possible; air or ground tanker attack likely to be ineffective.

Torching

Nil—no chance of torching.

Low—occasional tree may torch-out.

Medium—pole-sized understory trees likely to torch-out.

High—most of understory and occasional overstory trees likely to torch-out.

Extreme—entire stand likely to torch-out.

Crowning

Nil—sustained spread in crowns will not occur.

Low—sustained spread in crown unlikely.

Medium—some crowning likely but will not be continuous.

High—sustained crowning likely.

Extreme—sustained crowning will occur.

Resistance to Control

Nil—no physical impediments to line building and holding.

Low—occasional tough spots but not enough to cause serious line building and holding problems.

Medium—hand line construction will be difficult and slow, but dozers can operate without serious problems.

High—slow work for dozers, very difficult for hand crews; hand line holding will be difficult.

Extreme—neither dozers nor hand crews can effectively build and hold line.

Overall

Nil—fire will not sustain itself.

Low—fire can be easily controlled by several smokechasers with hand tools.

Medium—aggressive crew-sized (6-10 persons) initial attack required for successful control.

High—aggressive crew-sized (25 persons) initial attack with substantial reinforcement required for successful control; 10 percent chance that initial control action will fail.

Extreme—90 percent chance that initial control action will fail.

Procedures for using the photos to estimate fire potential are the same as those given for describing the fuel complex.

PHOTO GUIDE DEVELOPMENT

This photo guide was developed using the technique explained by Fischer (1981), which involved the following steps:

1. The fuel complexes photographed were selected to represent the range of fuel situations observed to exist for the cover type in Montana.
2. Sample plots are generally laid out and photographed in accordance with procedures suggested by USDA Forest Service (1975).
3. Fuels were sampled and described using fuel inventory and computational techniques developed by Brown (1974).
4. Habitat types are according to Pfister and others (1977). Cover types are according to SAF (1954).
5. Fire potential ratings are based on subjective evaluation by experienced fire managers using the adjective ratings and definitions in the preceding section of this guide.
6. National Fire Danger Rating fuel model assignment was by the author using definitions provided by Deeming and others (1977). Stylized fuel model assignment was by the author using definitions provided by Albini (1976).
7. The fire ecology group assignment was by the author using the definitions provided by Davis and others (1980).
8. Stand and site data were obtained using standard forestry field techniques.

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SERIES 1

LODGEPOLE PINE

SAF COVER TYPE 218

2

DATA SHEET

Stand No. 2

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 640, Subalpine fir/dwarf huckleberry (ABLA/VACA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.5	0.11
0.25-1	0.7	0.16
1-3	0.9	0.20
Subtotal 0-3	2.1	0.47
3-6	0.8	0.18
6-10	0	0
10-20	0.6	0.13
20+	0	0
SUBTOTAL 3+	1.4	0.31
TOTAL	3.5	0.78

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.3 in

3.30 cm

Average diameter, 3+fuels: 4.6 in

11.68 cm

Percent rotten, 3+fuels: 52 %

Volume of **sound** 3+fuels: 53 ft³/ac

3.7 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO	80 yrs
PSME	65 yrs

Average slope: 40 %

Aspect: south

Elevation 4350 ft 1326 m

Remarks:

Fire Ecology Group Seven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: E. Fk. Lolo Cr.

Photo taken: 9/15/76

By S. Cox

2

DATA SHEET

Stand No. 26A

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 283, Douglas-fir/blue huckleberry-beargrass phase (PSME/VAGL-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.2	0.04
0.25-1	0.4	0.09
1-3	0.7	0.16
Subtotal 0-3	1.3	0.29
3-6	1.9	0.43
6-10	0.8	0.18
10-20	0	0
20+	0	0
SUBTOTAL 3+	2.7	0.61
TOTAL	4.0	0.90

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 0.7 in
1.78 *cm*

Average diameter, 3+fuels:
4.0 in
10.16 *cm*

Percent rotten, 3+fuels: 23 %

Volume of **sound** 3+fuels:
171 ft³/ac
12.0 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PSME	150 yrs
PICO	107 yrs

Average slope: 24 %
Aspect: southwest
Elevation: 5390 ft 1643 *m*

Remarks:

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: low

Torching: nil

Crowning: nil

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Helena

Ranger District: Lincoln

Drainage: Keep Cool Cr.

Photo taken: 7/28/78

By: W. C. Fischer

DATA SHEET

Stand No. 1

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 640, Subalpine fir/dwarf huckleberry (ABLA/VACA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.6	0.13
0.25-1	0.9	0.20
1-3	3.8	0.85
Subtotal 0-3	5.3	1.18
3-6	1.4	0.31
6-10	0.4	0.08
10-20	0	0
20+	0	0
SUBTOTAL 3+	1.8	0.39
TOTAL	7.1	1.57

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.4 in
3.56 *cm*

Average diameter, 3+fuels: 4.2 in
10.67 *cm*

Percent rotten, 3+fuels: 12 %

Volume of **sound** 3+fuels: 131 ft³/ac
9.2 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PICO	80 yrs
PSME	65 yrs

Average slope: 30 %
Aspect: south
Elevation: 4350 ft 1326 *m*

Remarks:
Fire Ecology Group Seven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: low
Torching: low
Crowning: low
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: E. Fk. Lolo Cr.

Photo taken: 9/15/76
By: S. Cox

3
5

DATA SHEET

Stand No. 35A

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 720, Subalpine fir/blue huckleberry (ABLA/VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.3	0.07
0.25-1	1.2	0.27
1-3	5.1	1.14
Subtotal 0-3	6.6	1.48
3-6	4.3	0.96
6-10	1.1	0.25
10-20	0	0
20+	0	0
SUBTOTAL 3+	5.4	1.21
TOTAL	12.0	2.69

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H/G	8/10

OTHER FUEL DATA

Average duff depth: 2.4 in

6.10 *cm*

Average diameter, 3+fuels: 3.8 in

9.65 *cm*

Percent rotten, 3+fuels: 16 %

Volume of **sound** 3+fuels: 360 ft³/ac

25.2 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PICO 123 yrs

Average slope: 11 %

Aspect: northwest

Elevation: 6090 ft 1856 *m*

Remarks:

Fire Ecology Group Seven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lewis & Clark

Ranger District: White Sulphur Springs

Drainage: Fourmile Cr.

Photo taken: 8/10/78

By: W. C. Fischer

5
2

DATA SHEET

Stand No. 82

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 661, Subalpine fir/twinflower-twinflower (ABLA/LIBO-LIBO)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	0.3	0.07
1-3	1.5	0.34
Subtotal 0-3	2.1	0.48
3-6	1.7	0.38
6-10	7.3	1.64
10-20	1.6	0.36
20+	0	0
SUBTOTAL 3+	10.6	2.38
TOTAL	12.7	2.86

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.5 in

3.81 cm

Average diameter, 3+fuels:

6.1 in

15.49 cm

Percent rotten, 3+fuels: 89 %

Volume of **sound** 3+fuels:

90 ft³/ac

6.3 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO 55 yrs

Average slope: 30 %

Aspect: southeast

Elevation: 4420 ft 1347 m

Remarks:

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Howard Cr.

Photo taken: 8/22/77

By: W. C. Fischer

8
5

DATA SHEET

Stand No. 85

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 283, Douglas-fir/blue huckleberry-beargrass phase (PSME/VAGL-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.5	0.11
0.25-1	1.9	0.43
1-3	4.3	0.96
Subtotal 0-3	6.7	1.50
3-6	0.2	0.04
6-10	1.6	0.36
10-20	4.2	0.94
20+	0	0
SUBTOTAL 3+	6.0	1.34
TOTAL	12.7	2.84

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.2 in
5.59 cm

Average diameter, 3+fuels:
8.9 in
22.61 cm

Percent rotten, 3+fuels: 98 %

Volume of **sound** 3+fuels:
11 ft³/ac
0.8 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO	70 yrs
PSME	70 yrs

Average slope: 9 %
Aspect: northwest
Elevation: 5300 ft 1615 m

Remarks:

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: medium

Torching: medium

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Howard Cr.

Photo taken: 8/22/77

By: W. C. Fischer

2
5

DATA SHEET

Stand No. 25A

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 283, Douglas-fir/blue huckleberry-beargrass phase (PSME/VAGL-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.2	0.04
0.25-1	0.8	0.18
1-3	3.7	0.83
Subtotal 0-3	4.7	1.05
3-6	6.7	1.50
6-10	1.4	0.31
10-20	0	0
20+	0	0
SUBTOTAL 3+	8.1	1.81
TOTAL	12.8	2.86

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.0 in
2.54 cm

Average diameter, 3+fuels:
3.7 in
9.40 cm

Percent rotten, 3+fuels: 10 %

Volume of **sound** 3+fuels:
580 ft³/ac
40.6 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
PICO 120 yrs
PSME 95 yrs

Average slope: 15 %
Aspect: southwest
Elevation: 5120 ft 1561 m

Remarks.
Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: low
Torching: nil
Crowning: nil
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Helena
Ranger District: Lincoln
Drainage: Keep Cool Cr.

Photo taken: 7/28/78
By. W. C. Fischer

3
4

DATA SHEET

Stand No. 34A

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 940, Lodgepole pine/grouse whortleberry (PICO/VASC)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.4	0.09
0.25-1	1.9	0.43
1-3	8.5	1.91
Subtotal 0-3	10.8	2.43
3-6	2.1	0.47
6-10	0.2	0.04
10-20	0	0
20+	0	0
SUBTOTAL 3+	2.3	0.51
TOTAL	13.1	2.94

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.9 in
4.83 *cm*

Average diameter, 3+fuels: 3.5 in
8.89 *cm*

Percent rotten, 3+fuels: 15 %

Volume of **sound** 3+fuels: 157 ft³/ac
11.0 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:
PICO 85 yrs

Average slope: 7 %
Aspect: northwest
Elevation: 6170 ft 1881 *m*

Remarks:
Fire Ecology Group Seven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lewis & Clark

Ranger District: White Sulphur Springs

Drainage: Fourmile Cr.

Photo taken: 8/10/78

By: W. C. Fischer

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DATA SHEET

Stand No. 45A

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 250, Douglas-fir/dwarf huckleberry (PSME/VACA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.2	0.04
0.25-1	0.8	0.18
1-3	1.7	0.38
Subtotal 0-3	2.7	0.60
3-6	1.2	0.27
6-10	6.5	1.46
10-20	2.8	0.63
20+	0	0
SUBTOTAL 3+	10.5	2.36
TOTAL	13.2	2.96

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H/G	8/10

OTHER FUEL DATA

Average duff depth: 1.5 in

3.81 cm

Average diameter, 3+fuels: 6.5 in

16.51 cm

Percent rotten, 3+fuels: 99 %

Volume of **sound** 3+fuels: 8 ft³/ac

0.6 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO 51 yrs

Average slope: 15 %

Aspect: southwest

Elevation: 5600 ft 1707 m

Remarks:

Fire Ecology Groups Six (Westside)

and Seven (Eastside)

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Deerlodge

Ranger District: Philipsburg

Drainage: Henderson Cr.

Photo taken: 9/25/78

By: W. C. Fischer

DATA SHEET

Stand No. 47A

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 250, Douglas-fir/dwarf huckleberry (PSME/VACA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.1	0.02
0.25-1	1.0	0.22
1-3	3.3	0.74
Subtotal 0-3	4.4	0.98
3-6	3.3	0.74
6-10	5.4	1.21
10-20	4.0	0.90
20+	0	0
SUBTOTAL 3+	12.7	2.85
TOTAL	17.1	3.83

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H/G	8/10

OTHER FUEL DATA

Average duff depth: 2.5 in 6.35 *cm*

Average diameter, 3+fuels: 5.3 in 13.46 *cm*

Percent rotten, 3+fuels: 90 %

Volume of **sound** 3+fuels: 102 ft³/ac 7.1 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PSME	200+ yrs
PICO	180 yrs

Average slope: 8 %
Aspect: northwest
Elevation: 5950 ft 1814 *m*

Remarks:

Fire Ecology Group Seven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: low
Torching: low
Crowning: low
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Deerlodge
Ranger District: Philipsburg
Drainage: Henderson Cr.

Photo taken: 9/25/78
By. W. C. Fischer

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7

DATA SHEET

Stand No. 87

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 662, Subalpine fir/twinflower-beargrass phase (ABLA/VAGL-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.4	0.09
0.25-1	2.1	0.47
1-3	2.6	0.58
Subtotal 0-3	5.1	1.14
3-6	4.7	1.05
6-10	7.4	1.66
10-20	1.3	0.29
20+	0	0
SUBTOTAL 3+	13.4	3.00
TOTAL	18.5	4.14

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
K	11

OTHER FUEL DATA

Average duff depth: 2.1 in

5.33 cm

Average diameter, 3+fuels:

5.4 in

13.72 cm

Percent rotten, 3+fuels: 43 %

Volume of **sound** 3+fuels:

617 ft^3/ac

43.2 m^3/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME 155 yrs

LAOC 70 yrs

PICO 63 yrs

Average slope: 10 %

Aspect: northwest

Elevation 4550 ft 1387 m

Remarks: old thinning slash

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: medium

Torching: low

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: N. Fk. Howard Cr.

Photo taken: 8/29/77

By W. C. Fischer

S
3

DATA SHEET

Stand No. 83

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 292, Douglas-fir/twinflower-pinegrass phase (PSME/LIBO-CARU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.5	0.11
0.25-1	1.7	0.38
1-3	1.9	0.43
Subtotal 0-3	4.1	0.92
3-6	10.0	2.24
6-10	3.0	0.67
10-20	2.1	0.47
20+	0	0
SUBTOTAL 3+	15.1	3.38
TOTAL	19.2	4.30

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.7 in; 4.32 *cm*

Average diameter, 3+fuels: 4.3 in; 10.92 *cm*

Percent rotten, 3+fuels: 18 %

Volume of **sound** 3+fuels: 988 ft³/ac; 69.1 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PICO	50 yrs
LAOC	50 yrs

Average slope: 12 %

Aspect: southeast

Elevation: 4950 ft 1509 *m*

Remarks: old thinning slash

Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: low

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Howard Cr.

Photo taken: 8/22/77

By: W. C. Fischer

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2

DATA SHEET

Stand No. 92

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.6	0.13
0.25-1	1.9	0.43
1-3	6.2	1.39
Subtotal 0-3	8.7	1.95
3-6	6.6	1.48
6-10	2.7	0.61
10-20	1.5	0.34
20+	0	0
SUBTOTAL 3+	10.8	2.43
TOTAL	19.5	4.38

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
K/G	11/10

OTHER FUEL DATA

Average duff depth: 1.5 in
3.81 *cm*

Average diameter, 3+fuels: 4.2 in
10.67 *cm*

Percent rotten, 3+fuels: 42 %

Volume of **sound** 3+fuels: 498 ft³/ac
34.9 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

LAOC	280 yrs
PICO	55 yrs

Average slope: 30 %
Aspect: northwest
Elevation: 5270 ft 1606 *m*

Remarks: old thinning slash
Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: low
Crowning: low
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Howard Cr.

Photo taken: 8/29/77
By. W. C. Fischer

5
3

DATA SHEET

Stand No. 53

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	1.4	0.31
1-3	4.5	1.01
Subtotal 0-3	6.2	1.39
3-6	8.0	1.79
6-10	6.3	1.41
10-20	0	0
20+	0	0
SUBTOTAL 3+	14.3	3.20
TOTAL	20.5	4.59

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.9 in

4.83 *cm*

Average diameter, 3+fuels: 4.4 in

11.18 *cm*

Percent rotten, 3+fuels: 18 %

Volume of **sound** 3+fuels: 932 ft³/ac

65.2 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PICO	128 yrs
PSME	125 yrs
ABLA	100 yrs

Average slope: 60 %

Aspect northwest

Elevation: 5870 ft 1789 *m*

Remarks.

Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: medium

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Gilbert Cr.

Photo taken: 7/6/77

By W. C. Fischer

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DATA SHEET

Stand No. 41

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.2	0.04
0.25-1	1.1	0.25
1-3	2.9	0.65
Subtotal 0-3	4.2	0.94
3-6	8.3	1.86
6-10	7.3	1.64
10-20	2.1	0.47
20+	0	0
SUBTOTAL 3+	17.7	3.97
TOTAL	21.9	4.91

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.4 in

3.56 *cm*

Average diameter, 3+fuels:

4.7 in

11.94 *cm*

Percent rotten, 3+fuels: 54 %

Volume of **sound** 3+fuels:

652 ft^3/ac

45.6 m^3/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME 103 yrs

PICO 86 yrs

Average slope: 50 %

Aspect: northwest

Elevation: 6100 ft 1859 *m*

Remarks:

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

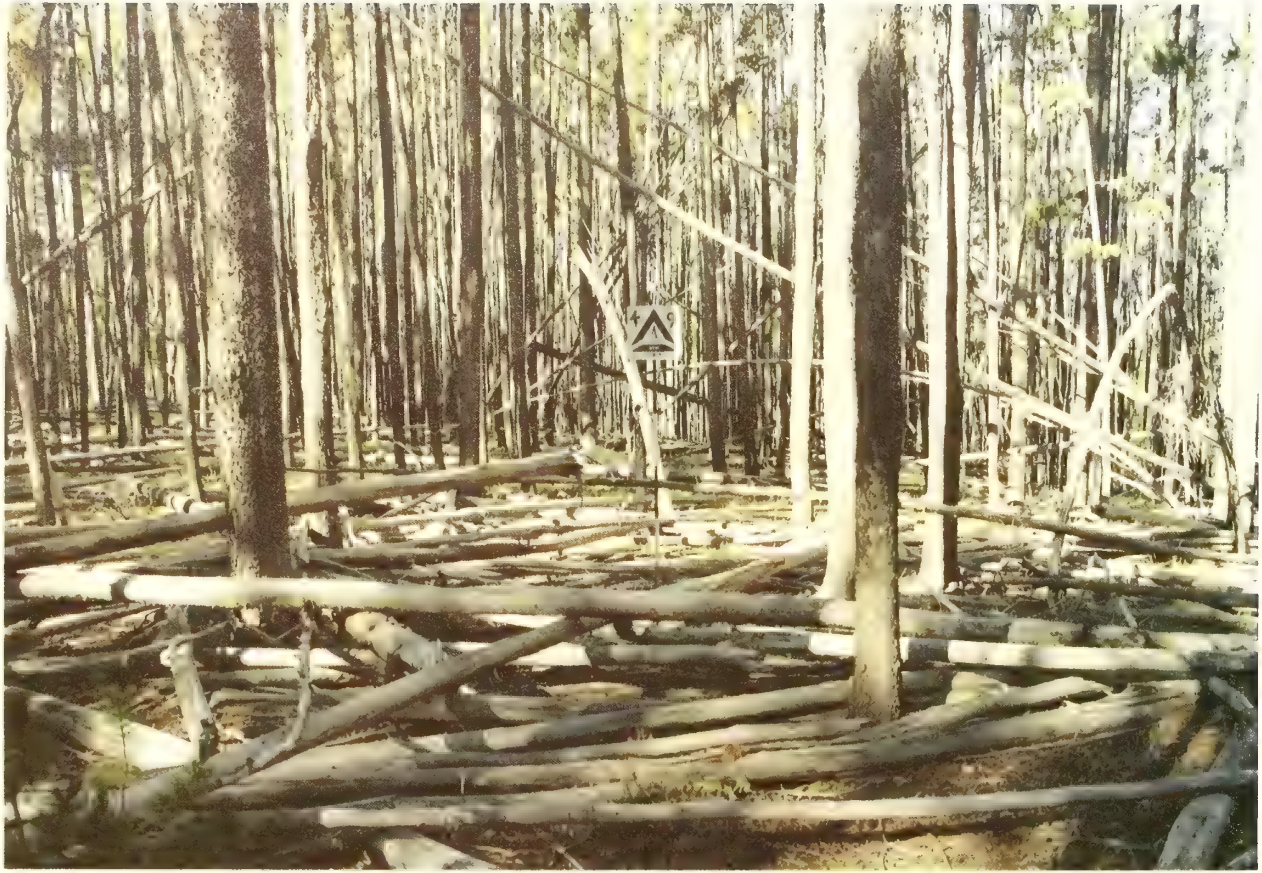
National Forest: Lolo

Ranger District: Missoula

Drainage: Gilbert Cr.

Photo taken: 6/23/77

By: W. C. Fischer



DATA SHEET

FOREST COVER TYPE, SAF NO. 15 Lodgepole pine

Stand No. 49A

Stand No. 49A

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 640, Subalpine fir/dwarf huckleberry (ABLA/VACA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	1.4	0.31
1-3	8.1	1.82
Subtotal 0-3	9.8	2.20
3-6	11.8	2.65
6-10	1.0	0.22
10-20	0	0
20+	0	0
SUBTOTAL 3+	12.8	2.87
TOTAL	22.6	5.07

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.3 in

5.84 cm

Average diameter, 3+fuels: 3.6 in

9.14 cm

Percent rotten, 3+fuels: 24 %

Volume of **sound** 3+fuels: 780 ft³/ac

54.6 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO 162 yrs

Average slope: 1 %

Aspect: northwest

Elevation: 6560 ft 1999 m

Remarks:

Fire Ecology Group Seven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: medium

Torching: low

Crowning: medium

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Deerlodge

Ranger District: Philipsburg

Drainage: Sand Basin Cr.

Photo taken: 10/5/78

By: W. C. Fischer

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8

DATA SHEET

Stand No. 98

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 690, Subalpine fir/beargrass (ABLA/XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	1.2	0.27
1-3	5.3	1.19
Subtotal 0-3	6.8	1.53
3-6	10.8	2.42
6-10	6.3	1.41
10-20	0	0
20+	0	0
SUBTOTAL 3+	17.1	3.83
TOTAL	23.9	5.36

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.0 in
5.08 cm

Average diameter, 3+fuels: 4.2 in
10.67 cm

Percent rotten, 3+fuels: 23 %

Volume of **sound** 3+fuels: 1059 ft³/ac
74.1 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO	145 yrs
PSME	130 yrs
PICEA	120 yrs

Average slope: 8 %
Aspect: northwest
Elevation: 6360 ft 1939 m

Remarks:
Fire Ecology Group Seven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: medium
Torching: low
Crowning: low
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: W. Fk. Tyle Cr.

Photo taken: 6/13/78
By: W. C. Fischer

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Stand No. 61

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.5	0.11
0.25-1	1.7	0.38
1-3	1.3	0.29
Subtotal 0-3	3.5	0.78
3-6	5.2	1.17
6-10	11.5	2.58
10-20	4.1	0.92
20+	0	0
SUBTOTAL 3+	20.8	4.67
TOTAL	24.8	5.45

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.8 in

7.11 cm

Average diameter, 3+fuels:

5.5 in

13.97 cm

Percent rotten, 3+fuels: 40 %

Volume of **sound** 3+fuels:

998 ft^3/ac

69.8 m^3/ha

STAND AND SITE DATA

Age of overstory dominants:

LAOC	137 yrs
PSME	127 yrs
PICO	123 yrs

Average slope: 30 %

Aspect: southwest

Elevation: 5120 ft 1561 m

Remarks:

Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: low

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Rattlesnake Cr.

Photo taken: 7/13/77

By: W. C. Fischer

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0

Stand No. 60

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 624, Subalpine fir/queencup beadlily-beargrass phase (ABLA/CLUN-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.3	0.07
0.25-1	0.8	0.18
1-3	0.4	0.09
Subtotal 0-3	1.5	0.34
3-6	7.5	1.68
6-10	12.3	2.76
10-20	6.5	1.46
20+	0	0
SUBTOTAL 3+	26.3	5.90
TOTAL	27.8	6.24

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.1 in
5.33 *cm*

Average diameter, 3+fuels: 5.4 in
13.72 *cm*

Percent rotten, 3+fuels: 28 %

Volume of **sound** 3+fuels: 1516 ft^3/ac
106.1 *m^3/ha*

STAND AND SITE DATA

Age of overstory dominants:

LAOC	432 yrs
PICO	147 yrs
PICEA	100 yrs

Average slope: 14 %
Aspect: southeast
Elevation: 5140 ft 1567 *m*

Remarks:
Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: medium
Torching: medium
Crowning: low
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Rattlesnake Cr.

Photo taken: 7/13/77
By: W. C. Fischer

Stand No. 60

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 624, Subalpine fir/queencup beadlily-beargrass phase (ABLA/CLUN-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	0.8	0.18
1-3	0.4	0.09
Subtotal 0-3	1.5	0.34
3-6	7.5	1.68
6-10	12.3	2.76
10-20	6.5	1.46
20+	0	0
SUBTOTAL 3+	26.3	5.90
TOTAL	27.8	6.24

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.1 in
5.33 cm

Average diameter, 3+fuels: 5.4 in
13.72 cm

Percent rotten, 3+fuels: 28 %

Volume of **sound** 3+fuels: 1516 ft³/ac
106.1 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
LAOC 432 yrs
PICO 147 yrs
PICEA 100 yrs

Average slope: 14 %
Aspect: southeast
Elevation: 5140 ft 1567 m

Remarks:
Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: medium
Torching: medium
Crowning: low
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Rattlesnake Cr.

Photo taken: 7/13/77
By: W. C. Fischer

Stand No. 55

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 283, Douglas fir/blue huckleberry-beargrass phase (PSME/VAGL-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	1.4	0.31
1-3	2.1	0.47
Subtotal 0-3	3.8	0.85
3-6	10.8	2.42
6-10	14.6	3.27
10-20	1.0	0.22
20+	0	0
SUBTOTAL 3+	26.4	5.91
TOTAL	30.2	6.76

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.2 in
3.05 *cm*

Average diameter, 3+fuels:
5.0 in
12.70 *cm*

Percent rotten, 3+fuels: 13 %

Volume of **sound** 3+fuels:
1858 ft³/ac
130.0 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PICO	170 yrs
PSME	140 yrs

Average slope: 60 %
Aspect: southwest
Elevation: 6030 ft 1838 *m*

Remarks:
Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: low
Crowning: low
Resistance to control: low

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Gilbert Cr.

Photo taken: 7/6/77
By: W. C. Fischer

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Stand No. 48A

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 250, Douglas-fir/dwarf huckleberry (PSME/VACA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.2	0.04
0.25-1	1.0	0.22
1-3	1.2	0.27
Subtotal 0-3	2.4	0.53
3-6	4.2	0.94
6-10	14.9	3.34
10-20	10.2	2.29
20+	0	0
SUBTOTAL 3+	29.3	6.57
TOTAL	31.7	7.10

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.2 in

5.59 cm

Average diameter, 3+fuels: 6.4 in

16.26 cm

Percent rotten, 3+fuels: 66 %

Volume of **sound** 3+fuels: 790 ft³/ac

55.3 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO	130 yrs
PSME	114 yrs

Average slope: 20 %

Aspect: east

Elevation 6230 ft 1899 m

Remarks:

Fire Ecology Group Six (westside)

and Seven (eastside)

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: high

Intensity: medium

Torching: high

Crowning: medium

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Deerlodge

Ranger District: Philipsburg

Drainage: Henderson Cr.

Photo taken: 9/25/78

By: W. C. Fischer

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Stand No. 11

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.5	0.11
0.25-1	1.5	0.34
1-3	5.0	1.12
Subtotal 0-3	7.0	1.57
3-6	7.0	1.57
6-10	4.1	0.92
10-20	13.9	3.12
20+	0	0
SUBTOTAL 3+	25.0	5.61
TOTAL	32.0	7.18

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.2 in

3.05 *cm*

Average diameter, 3+fuels:

5.4 in

13.72 *cm*

Percent rotten, 3+fuels: 34 %

Volume of **sound** 3+fuels:

1328 ft^3/ac

92.9 m^3/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO 60 yrs

Average slope: 10 %

Aspect: north

Elevation: 5760 ft 1756 *m*

Remarks: small amount of pole and post cutting slash present

Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: medium

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Cloudburst Cr.

Photo taken: 9/21/76

By: W. C. Fischer

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6

DATA SHEET

Stand No. 46A

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 250, Douglas-fir/dwarf huckleberry (PSME/VACA)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.2	0.04
0.25-1	0.7	0.16
1-3	1.2	0.27
Subtotal 0-3	2.1	0.47
3-6	10.7	2.40
6-10	17.0	3.81
10-20	2.5	0.56
20+	0	0
SUBTOTAL 3+	30.2	6.77
TOTAL	32.3	7.24

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.5 in

6.35 cm

Average diameter, 3+fuels: 5.1 in

12.95 cm

Percent rotten, 3+fuels: 77 %

Volume of **sound** 3+fuels: 551 ft³/ac

38.6 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO 55 yrs

Average slope: 5 %

Aspect: northeast

Elevation: 5880 ft 1792 m

Remarks:

Fire Ecology Group Six (westside) and Seven (eastside)

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: medium

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Deerlodge

Ranger District: Philipsburg

Drainage: Henderson Cr.

Photo taken: 9/25/78

By: W. C. Fischer

DATA SHEET

Stand No. 27

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 292, Douglas-fir/twinflower-pinegrass phase (PSME/LIBO-CARU)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	1.7	0.38
1-3	3.2	0.72
Subtotal 0-3	5.2	1.17
3-6	5.0	1.12
6-10	14.3	3.21
10-20	8.8	1.97
20+	0	0
SUBTOTAL 3+	28.1	6.30
TOTAL	33.3	7.47

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.3 in
5.84 cm

Average diameter, 3+fuels:
6.3 in
16.00 cm

Percent rotten, 3+fuels: 93 %

Volume of **sound** 3+fuels:
152 ft³/ac
10.6 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
PSME 140 yrs

Average slope: 48 %
Aspect: east
Elevation: 5150 ft 1570 m

Remarks:
Fire Ecology Group Six

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: medium

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: W. Fk. Swartz Cr.

Photo taken 6/20/77

By W. C. Fischer

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Stand No. 81

FOREST COVER TYPE: SAF NO. 218, Lodgepole pine

MONTANA HABITAT TYPE: NO. 470, Spruce/twinflower (PICEA/LIBO)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	0.8	0.18
1-3	2.4	0.54
Subtotal 0-3	3.5	0.79
3-6	2.8	0.63
6-10	6.3	1.41
10-20	22.1	4.95
20+	0	0
SUBTOTAL 3+	31.2	6.99
TOTAL	34.7	7.78

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.6 in
4.06 cm

Average diameter, 3+fuels:
7.7 in
19.56 cm

Percent rotten, 3+fuels: 31 %

Volume of **sound** 3+fuels:
1722 ft³/ac
120.5 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
PICO 50 yrs

Average slope: 23 %
Aspect northwest
Elevation: 4400 ft 1341 m

Remarks

Fire Ecology Group Seven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Howard Cr.

Photo taken: 8/22/77

By W. C. Fischer

SERIES 2

ENGELMANN SPRUCE - SUBALPINE FIR

SAF COVER TYPE 206

4
5

Stand No. 45

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	0.6	0.13
1-3	0.3	0.07
Subtotal 0-3	1.2	0.27
3-6	0.1	0.02
6-10	0	0
10-20	0	0
20+	0	0
SUBTOTAL 3+	0.1	0.02
TOTAL	1.3	0.29

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.3 in
3.30 cm

Average diameter, 3+fuels: 3.0 in
7.62 cm

Percent rotten, 3+fuels: 100 %

Volume of **sound** 3+fuels: 0 ft³/ac
0 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	86 yrs
PICO	57 yrs
ABLA	55 yrs

Average slope: 40 %
Aspect: southeast
Elevation: 6280 ft 1914 m

Remarks: Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: low
Torching: low
Crowning: low
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Gilbert Cr.

Photo taken: 6/24/77
By: W. C. Fischer

DATA SHEET

Stand No. 1A

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.4	0.09
0.25-1	1.9	0.43
1-3	3.3	0.74
Subtotal 0-3	5.6	1.26
3-6	0.9	0.20
6-10	0	0
10-20	0	0
20+	0	0
SUBTOTAL 3+	0.9	0.20
TOTAL	6.5	1.46

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 2.9 in
7.37 cm

Average diameter, 3+fuels:
3.3 in
8.38 cm

Percent rotten, 3+fuels: 79 %

Volume of **sound** 3+fuels:
14 ft³/ac
1.0 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PIMO	120 yrs
PICO	77 yrs
ABLA	75 yrs
PSME	70 yrs

Average slope: 6 %
Aspect: southwest
Elevation: 5480 ft 1670 m

Remarks:
Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: medium
Torching: medium
Crowning: high
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Kootenai
Ranger District: Libby
Drainage: Hennesey Cr.

Photo taken: 6/26/78
By. W. C. Fischer

Stand No. 40

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.2	0.04
0.25-1	1.8	0.40
1-3	1.6	0.36
Subtotal 0-3	3.6	0.80
3-6	1.4	0.31
6-10	1.5	0.34
10-20	0	0
20+	0	0
SUBTOTAL 3+	2.9	0.65
TOTAL	6.5	1.45

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 2.5 in 6.35 cm

Average diameter, 3+fuels: 5.3 in 13.46 cm

Percent rotten, 3+fuels: 81 %

Volume of **sound** 3+fuels: 45 ft³/ac 3.2 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO	68 yrs
PSME	53 yrs

Average slope: 40 %

Aspect northwest

Elevation 6130 ft 1868 m

Remarks:

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Gilbert Cr.

Photo taken: 6/23/77

By W. C. Fischer

DATA SHEET

Stand No. 39

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.1	0.02
0.25-1	0.4	0.09
1-3	1.4	0.09
Subtotal 0-3	0.9	0.20
3-6	3.3	0.74
6-10	3.0	0.67
10-20	0	0
20+	0	0
SUBTOTAL 3+	6.3	1.41
TOTAL	7.2	1.61

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 1.2 in

3.05 *cm*

Average diameter, 3+fuels: 4.5 in

11.43 *cm*

Percent rotten, 3+fuels: 42 %

Volume of **sound** 3+fuels: 292 ft^3/ac

20.4 m^3/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO	130 yrs
ABLA	110 yrs
PIAL	105 yrs

Average slope: 40 %

Aspect northwest

Elevation 6135 ft 1870 *m*

Remarks

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Gilbert Cr.

Photo taken 6/23/77

By W. C. Fischer

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5

Stand No. 35

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.2	0.04
0.25-1	1.0	0.22
1-3	3.3	0.74
Subtotal 0-3	4.5	1.00
3-6	4.5	1.01
6-10	0	0
10-20	0	0
20+	0	0
SUBTOTAL 3+	4.5	1.01
TOTAL	9.0	2.01

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 0.9 in

2.29 cm

Average diameter, 3+fuels: 3.7 in

9.40 cm

Percent rotten, 3+fuels: 22 %

Volume of **sound** 3+fuels: 282 ft³/ac

19.7 m³/ha

STAND AND SITE DATA

Age of overstory dominants: PICO 110 yrs

Average slope 9 %

Aspect: northwest

Elevation 6640 ft 2024 m

Remarks

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District Missoula

Drainage Gilbert Cr.

Photo taken 6/23/77

By W. C. Fischer

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DATA SHEET

Stand No. 2A

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - Subalpine fir

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.6	0.13
0.25-1	1.5	0.34
1-3	2.9	0.65
Subtotal 0-3	5.0	1.12
3-6	2.3	0.52
6-10	2.0	0.45
10-20	0	0
20+	0	0
SUBTOTAL 3+	4.3	0.97
TOTAL	9.3	2.09

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H/G	8/10

OTHER FUEL DATA

Average duff depth: 2.2 in
5.59 cm

Average diameter, 3+ fuels: 4.8 in
12.19 cm

Percent rotten, 3+ fuels: 57 %

Volume of **sound** 3+ fuels: 150 ft³/ac
10.5 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PIMO	78 yrs
PSME	77 yrs
PICO	76 yrs
ABGR	70 yrs

Average slope 16 %
Aspect southwest
Elevation 5100 ft 1554 m

Remarks

Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: low
Crowning: medium
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Kootenia
Ranger District: Libby
Drainage: Hennesey Cr.

Photo taken 6/26/78
By W. C. Fischer

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Stand No. 26

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 621, Subalpine fir/queencup beadlily-queencup beadlily phase (ABLA/CLUN-CLUN)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.8	0.18
0.25-1	2.0	0.45
1-3	3.3	0.74
Subtotal 0-3	6.1	1.37
3-6	3.0	0.67
6-10	1.1	0.25
10-20	1.0	0.22
20+	0	0
SUBTOTAL 3+	5.1	1.14
TOTAL	11.2	2.51

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H/G	8/10

OTHER FUEL DATA

Average duff depth: 3.3 in, 8.38 cm

Average diameter, 3+fuels: 4.2 in, 10.67 cm

Percent rotten, 3+fuels: 30 %

Volume of **sound** 3+fuels: 281 ft³/ac, 19.7 m³/ha

STAND AND SITE DATA

Age of overstory dominants

PSME	100 yrs
LAOC	93 yrs
PICEA	87 yrs
ABLA	80 yrs

Average slope 20 %

Aspect south

Elevation 3450 ft 1052 m

Remarks stream-side

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: medium

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Ninemile

Drainage: Butler Cr.

Photo taken 9/24/76

By W. C. Fischer

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4
A

DATA SHEET

Stand No. 24A

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 692, Subalpine fir/beargrass-grouse whortleberry phase (ABLA/XETE-VASC)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	1.0	0.22
1-3	2.5	0.56
Subtotal 0-3	3.8	0.85
3-6	7.7	1.73
6-10	1.3	0.29
10-20	0	0
20+	0	0
SUBTOTAL 3+	9.0	2.02
TOTAL	12.8	2.87

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H	8

OTHER FUEL DATA

Average duff depth: 0.8 in
2.03 cm

Average diameter, 3+fuels: 3.7 in
9.40 cm

Percent rotten, 3+fuels: 8 %

Volume of **sound** 3+fuels: 654 ft³/ac
45.8 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	160 yrs
PICO	140 yrs
ABLA	93 yrs

Average slope: 10 %
Aspect: southeast
Elevation: 5020 ft 1530 m

Remarks:
Fire Ecology Group Seven

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: medium
Crowning: low
Resistance to control: low

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Helena
Ranger District: Lincoln
Drainage: Keep Cool Cr.

Photo taken: 7/28/78
By: W. C. Fischer

DATA SHEET

Stand No. 44

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.6	0.13
0.25-1	2.6	0.58
1-3	7.6	1.70
Subtotal 0-3	10.8	2.41
3-6	5.5	1.23
6-10	1.1	0.25
10-20	0	0
20+	0	0
SUBTOTAL 3+	6.6	1.48
TOTAL	17.4	3.89

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.6 in

4.06 cm

Average diameter, 3+fuels:

3.8 in

9.65 cm

Percent rotten, 3+fuels: 30 %

Volume of **sound** 3+fuels:

372 ft³/ac

26.0 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICO	90 yrs
PSME	70 yrs

Average slope: 60 %

Aspect: north

Elevation: 6300 ft 1920 m

Remarks:

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: high

Intensity: high

Torching: high

Crowning: medium

Resistance to control: medium

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Gilbert Cr.

Photo taken: 6/24/77

By: W. C. Fischer

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1

DATA SHEET

Stand No. 37

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.3	0.07
0.25-1	1.9	0.43
1-3	4.1	0.92
Subtotal 0-3	6.3	1.42
3-6	6.4	1.43
6-10	4.6	1.03
10-20	1.3	0.29
20+	0	0
SUBTOTAL 3+	12.3	2.75
TOTAL	18.6	4.17

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.0 in
5.08 cm

Average diameter, 3+fuels:
4.7 in
11.94 cm

Percent rotten, 3+fuels: 33 %

Volume of **sound** 3+fuels:
656 ft³/ac
45.9 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICEA	225 yrs
ABLA	130 yrs

Average slope: 40 %
Aspect: northwest
Elevation: 6440 ft 1963 m

Remarks:
Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: medium
Torching: medium
Crowning: medium
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Gilbert Cr.

Photo taken: 6/23/77
By: W. C. Fischer

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Stand No. 21

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 624, Subalpine fir/queencup beadlily-beargrass (ABLA/CLUN-XETE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.7	0.16
0.25-1	1.3	0.29
1-3	3.1	0.69
Subtotal 0-3	5.1	1.14
3-6	4.0	0.90
6-10	2.7	0.61
10-20	8.4	1.88
20+	0	0
SUBTOTAL 3+	15.1	3.39
TOTAL	20.2	4.53

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.5 in
3.81 *cm*

Average diameter, 3+fuels: 5.8 in
14.73 *cm*

Percent rotten, 3+fuels: 1 %

Volume of **sound** 3+fuels: 1198 ft³/ac
83.8 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

LAOC	287 yrs
PSME	81 yrs
PICO	75 yrs
ABLA	75 yrs

Average slope: 17 %
Aspect: east
Elevation: 5350 ft 1631 *m*

Remarks:
Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo

Ranger District: Ninemile

Drainage: Bear Cr.

Photo taken: 9/23/76

By W. C. Fischer

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DATA SHEET

Stand No. 21A

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.2	0.04
0.25-1	0.9	0.20
1-3	1.9	0.43
Subtotal 0-3	3.0	0.67
3-6	9.7	2.17
6-10	7.5	1.68
10-20	0	0
20+	0	0
SUBTOTAL 3+	17.2	3.85
TOTAL	20.2	4.52

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
H/G	8/10

OTHER FUEL DATA

Average duff depth: 2.5 in
6.35 *cm*

Average diameter, 3+fuels: 4.5 in
11.43 *cm*

Percent rotten, 3+fuels: 41 %

Volume of **sound** 3+fuels: 812 ft^3/ac
56.8 *m^3/ha*

STAND AND SITE DATA

Age of overstory dominants:

PICEA	173 yrs
PIAL	157 yrs
ABLA	124 yrs

Average slope: 8 %
Aspect: northwest
Elevation: 6160 ft 1878 *m*

Remarks: Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90 ° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: low
Torching: nil
Crowning: nil
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Helena
Ranger District: Lincoln
Drainage: Cooper Cr.

Photo taken: 7/21/78
By: W. C. Fischer

DATA SHEET

Stand No. 90

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 661, Subalpine fir/twinflower-twinflower phase (ABLA/LIBO-LIBO)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.5	0.11
0.25-1	2.2	0.49
1-3	4.3	0.96
Subtotal 0-3	7.0	1.56
3-6	3.4	0.76
6-10	0.4	0.09
10-20	4.7	1.05
20+	6.0	1.35
SUBTOTAL 3+	14.5	3.25
TOTAL	21.5	4.81

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
C	2

OTHER FUEL DATA

Average duff depth: 2.1 in

5.33 *cm*

Average diameter, 3+fuels:

5.4 in

13.72 *cm*

Percent rotten, 3+fuels: 1 %

Volume of **sound** 3+fuels:

1159 ft³/ac

81.1 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

LAOC	120 yrs
PSME	63 yrs
PICO	52 yrs

Average slope: 52 %

Aspect: northeast

Elevation: 4040 ft 1231 *m*

Remarks: old partial cut

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: low

Crowning: nil

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Howard Cr.

Photo taken: 8/29/77

By W. C. Fischer

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4

DATA SHEET

Stand No. 54

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.7	0.16
0.25-1	2.7	0.61
1-3	4.1	0.92
Subtotal 0-3	7.5	1.69
3-6	6.8	1.52
6-10	6.0	1.35
10-20	1.5	0.34
20+	0	0
SUBTOTAL 3+	14.3	3.21
TOTAL	21.8	4.90

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.5 in
6.35 *cm*

Average diameter, 3+fuels:
4.8 in
12.19 *cm*

Percent rotten, 3+fuels: 53 %

Volume of **sound** 3+fuels:
532 ft³/ac
37.2 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PSME	295 yrs
PICEA	110 yrs
PICO	89 yrs

Average slope: 50 %
Aspect: northwest
Elevation: 5900 ft 1798 *m*

Remarks:
Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: high
Intensity: high
Torching: medium
Crowning: low
Resistance to control: medium

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Gilbert Cr.

Photo taken: 7/6/77
By: W. C. Fischer

DATA SHEET

Stand No. 36

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.4	0.09
0.25-1	2.0	0.45
1-3	2.9	0.65
Subtotal 0-3	5.3	1.19
3-6	8.1	1.82
6-10	8.9	2.00
10-20	0	0
20+	0	0
SUBTOTAL 3+	17.0	3.82
TOTAL	22.3	5.01

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.6 in
6.60 cm

Average diameter, 3+fuels:
4.7 in
11.94 cm

Percent rotten, 3+fuels: 66 %

Volume of **sound** 3+fuels:
459 ft^3/ac
32.1 m^3/ha

STAND AND SITE DATA

Age of overstory dominants:
PIAL 190 yrs
ABLA 130 yrs

Average slope: 30 %
Aspect: northwest
Elevation: 6620 ft 2018 m

Remarks:
Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: medium
Torching: medium
Crowning: medium
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Gilbert Cr.

Photo taken: 6/23/77
By: W. C. Fischer

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2

DATA SHEET

Stand No. 22A

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.5	0.11
0.25-1	1.8	0.40
1-3	2.0	0.45
Subtotal 0-3	4.3	0.96
3-6	5.9	1.32
6-10	9.4	2.11
10-20	2.9	0.65
20+	0	0
SUBTOTAL 3+	18.2	4.08
TOTAL	22.5	5.04

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.9 in

4.83 cm

Average diameter, 3+fuels:

5.2 in

13.21 cm

Percent rotten, 3+fuels: 37 %

Volume of **sound** 3+fuels:

926 ft³/ac

64.8 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

ABLA	184 yrs
PIAL	144 yrs
PICEA	115 yrs
PICO	115 yrs

Average slope: 5 %

Aspect: northwest

Elevation: 6020 ft 1835 m

Remarks:

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Helena

Ranger District: Lincoln

Drainage: Cooper Cr.

Photo taken: 7/21/78

By: W. C. Fischer

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DATA SHEET

Stand No. 50

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.7	0.16
0.25-1	2.8	0.63
1-3	1.6	0.36
Subtotal 0-3	5.1	1.15
3-6	2.0	0.45
6-10	9.5	2.13
10-20	7.8	1.75
20+	0	0
SUBTOTAL 3+	19.3	4.33
TOTAL	24.4	5.48

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 3.6 in

9.14 *cm*

Average diameter, 3+fuels:

6.7 in

17.02 *cm*

Percent rotten, 3+fuels: 41 %

Volume of **sound** 3+fuels:

913 ft³/ac

63.9 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PSME 153 yrs

ABLA 120 yrs

Average slope: 60 %

Aspect: northeast

Elevation: 5790 ft 1765 *m*

Remarks:

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Gilbert Cr.

Photo taken: 6/24/77

By: W. C. Fischer

DATA SHEET

Stand No. 58

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.3	0.07
0.25-1	1.2	0.27
1-3	2.1	0.47
Subtotal 0-3	3.6	0.81
3-6	2.0	0.45
6-10	10.8	2.42
10-20	9.0	2.02
20+	1.9	0.43
SUBTOTAL 3+	23.7	5.32
TOTAL	27.3	6.13

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.6 in

4.06 *cm*

Average diameter, 3+fuels:

7.2 in

18.29 *cm*

Percent rotten, 3+fuels: 33 %

Volume of **sound** 3+fuels:

1280 ft^3/ac

89.6 m^3/*ha*

STAND AND SITE DATA

Age of overstory dominants:

ABLA	132 yrs
PICEA	121 yrs
PICO	103 yrs

Average slope: 28 %

Aspect: southwest

Elevation: 5720 ft 1743 *m*

Remarks:

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: medium

Torching: medium

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Wrangle Cr.

Photo taken: 7/13/77

By: W. C. Fischer

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NATIONAL
SYSTEM

DATA SHEET

Stand No. 19

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.3	0.07
0.25-1	0.9	0.20
1-3	2.9	0.65
Subtotal 0-3	4.1	0.92
3-6	7.7	1.73
6-10	14.6	3.27
10-20	1.6	0.36
20+	0	0
SUBTOTAL 3+	23.9	5.36
TOTAL	28.0	6.28

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.2 in

3.05 *cm*

Average diameter, 3+fuels:

5.1 in

12.95 *cm*

Percent rotten, 3+fuels: 9 %

Volume of **sound** 3+fuels:

1731 ft³/ac

121.1 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

ABLA	120 yrs
PICO	117 yrs
PICEA	100 yrs

Average slope: 10 %

Aspect: northeast

Elevation: 5750 ft 1753 *m*

Remarks:

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: medium

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Ninemile

Drainage: Bear Cr.

Photo taken: 9/22/76

By: W. C. Fischer

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Stand No. 57

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 625, Subalpine fir/queencup beadlily-menziesia phase (ABLA/CLUN-MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.2	0.04
0.25-1	1.1	0.25
1-3	0.6	0.13
Subtotal 0-3	1.9	0.42
3-6	1.7	0.38
6-10	11.1	2.49
10-20	17.8	3.90
20+	0	0
SUBTOTAL 3+	30.6	6.77
TOTAL	32.5	7.19

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 4.0 in
10.16 cm

Average diameter, 3+fuels:
8.0 in
20.32 cm

Percent rotten, 3+fuels: 25 %

Volume of **sound** 3+fuels:
1834 ft^3/ac
128.3 m^3/ha

STAND AND SITE DATA

Age of overstory dominants:

PICEA	150 yrs
PSME	132 yrs
ABLA	120 yrs

Average slope: 30 %
Aspect: northeast
Elevation: 5500 ft 1676 m

Remarks

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: low
Torching: low
Crowning: low
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Wrangle Cr.

Photo taken: 7/13/77
By: W. C. Fischer

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DATA SHEET

Stand No. 96

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.7	0.16
0.25-1	1.6	0.36
1-3	1.8	0.40
Subtotal 0-3	4.1	0.92
3-6	4.4	0.99
6-10	17.2	3.86
10-20	7.8	1.75
20+	0	0
SUBTOTAL 3+	29.4	6.60
TOTAL	33.5	7.52

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.8 in

7.11 *cm*

Average diameter, 3+fuels:

6.4 in

16.26 *cm*

Percent rotten, 3+fuels: 54 %

Volume of **sound** 3+fuels:

1078 ft³/ac

75.4 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PSME	250 yrs
PICO	190 yrs
PICEA	143 yrs
ABLA	112 yrs

Average slope: 17 %

Aspect: northwest

Elevation: 5300 ft 1615 *m*

Remarks:

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: medium

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Gillispie Cr.

Photo taken: 6/13/78

By: W. C. Fischer

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Stand No. 23A

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.6	0.13
0.25-1	1.9	0.43
1-3	3.2	0.72
Subtotal 0-3	5.7	1.28
3-6	11.7	2.62
6-10	16.3	3.65
10-20	0	0
20+	0	0
SUBTOTAL 3+	28.0	6.27
TOTAL	33.7	7.55

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 3.1 in
7.87 *cm*

Average diameter, 3+fuels:
4.8 in
12.19 *cm*

Percent rotten, 3+fuels: 23 %

Volume of **sound** 3+fuels:
1733 ft³/ac
121.3 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

ABLA	150 yrs
PSME	140 yrs
PICEA	130 yrs
PICO	115 yrs

Average slope: 6 %
Aspect: northwest
Elevation: 5890 ft 1795 *m*

Remarks:
Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: high
Intensity: medium
Torching: medium
Crowning: medium
Resistance to control: high

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Helena
Ranger District: Lincoln
Drainage: Cooper Cr.

Photo taken: 7/21/78
By: W. C. Fischer

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Stand No. 46

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.7	0.16
0.25-1	2.3	0.52
1-3	6.0	1.35
Subtotal 0-3	9.0	2.03
3-6	2.6	0.58
6-10	7.8	1.75
10-20	18.9	4.24
20+	0	0
SUBTOTAL 3+	29.3	6.57
TOTAL	38.3	8.60

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 3.9 in
9.91 *cm*

Average diameter, 3+fuels:
7.8 in
19.81 *cm*

Percent rotten, 3+fuels: 84 %

Volume of **sound** 3+fuels:
367 ft³/ac
25.7 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PSME	357 yrs
ABLA	65 yrs
PICEA	55 yrs

Average slope: 60 %
Aspect: northeast
Elevation: 6000 ft 1829 *m*

Remarks:
Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: medium
Crowning: medium
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Gilbert Cr.

Photo taken: 6/24/77
By: W. C. Fischer

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Stand No. 97

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 661, Subalpine fir/twinflower-twinflower phase (ABLA/LIBO-LIBO)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.9	0.20
0.25-1	1.8	0.40
1-3	2.8	0.63
Subtotal 0-3	5.5	1.23
3-6	8.8	1.97
6-10	20.4	4.57
10-20	4.8	1.08
20+	0	0
SUBTOTAL 3+	34.0	7.62
TOTAL	39.5	8.85

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 3.1 in
7.87 *cm*

Average diameter, 3+fuels:
5.7 in
14.48 *cm*

Percent rotten, 3+fuels: 72 %

Volume of **sound** 3+fuels:
767 ft³/ac
53.7 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PICO	115 yrs
PICEA	108 yrs
ABLA	102 yrs

Average slope: 3 %
Aspect: northwest
Elevation: 5300 ft 1615 *m*

Remarks:
Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: low
Crowning: low
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Gillispie Cr.

Photo taken: 6/13/78
By: W. C. Fischer

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DATA SHEET

Stand No. 20

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 625, Subalpine fir/queencup beadlily-menziesia (ABLA/CLUN-MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.7	0.16
0.25-1	1.6	0.36
1-3	3.5	0.78
Subtotal 0-3	5.8	1.30
3-6	4.6	1.03
6-10	6.0	1.35
10-20	23.5	5.27
20+	0	0
SUBTOTAL 3+	34.1	7.65
TOTAL	39.9	8.95

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 3.4 in

8.64 *cm*

Average diameter, 3+fuels:

6.9 in

17.53 *cm*

Percent rotten, 3+fuels: 6 %

Volume of **sound** 3+fuels:

2556 ft^3/ac

178.8 m^3/ha

STAND AND SITE DATA

Age of overstory dominants:

LAOC	110 yrs
PICEA	92 yrs
ABLA	60 yrs

Average slope: 10 %

Aspect: east

Elevation: 5370 ft 1637 *m*

Remarks

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: medium

Torching: medium

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Ninemile

Drainage: Bear Cr.

Photo taken: 9/23/76

By: W. C. Fischer

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DATA SHEET

Stand No. 59

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.4	0.09
0.25-1	1.4	0.31
1-3	2.1	0.47
Subtotal 0-3	3.9	0.87
3-6	9.4	2.11
6-10	24.7	5.54
10-20	2.8	0.63
20+	0	0
SUBTOTAL 3+	36.9	8.28
TOTAL	40.8	9.15

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.3 in

3.30 *cm*

Average diameter, 3+fuels:

5.6 in

14.22 *cm*

Percent rotten, 3+fuels: 12 %

Volume of **sound** 3+fuels:

2596 ft^3/ac

181.6 m^3/*ha*

STAND AND SITE DATA

Age of overstory dominants:

ABLA 120 yrs

PSME 118 yrs

Average slope: 24 %

Aspect: southeast

Elevation 5620 ft 1713 *m*

Remarks:

Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: medium

Torching: medium

Crowning: low

Resistance to control: high

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Wrangle Cr.

Photo taken: 7/13/77

By W. C. Fischer

DATA SHEET

Stand No. 44A

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 440, Spruce/sweetscented bedstraw (PICEA/GATR)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight *Kg/m²*
0-0.25	0.4	0.09
0.25-1	1.8	0.40
1-3	4.1	0.92
Subtotal 0-3	6.3	1.41
3-6	3.0	0.67
6-10	5.5	1.23
10-20	28.7	6.43
20+	0	0
SUBTOTAL 3+	37.2	8.33
TOTAL	43.5	9.74

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 4.9 in
12.45 *cm*

Average diameter, 3+fuels:
7.5 in
19.05 *cm*

Percent rotten, 3+fuels: 50 %

Volume of **sound** 3+fuels:
1476 ft³/ac
103.3 *m³/ha*

STAND AND SITE DATA

Age of overstory dominants:

PICEA	200+ yrs
PSME	200+ yrs

Average slope: 7 %
Aspect northwest
Elevation: 6270 ft 1911 *m*

Remarks
Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

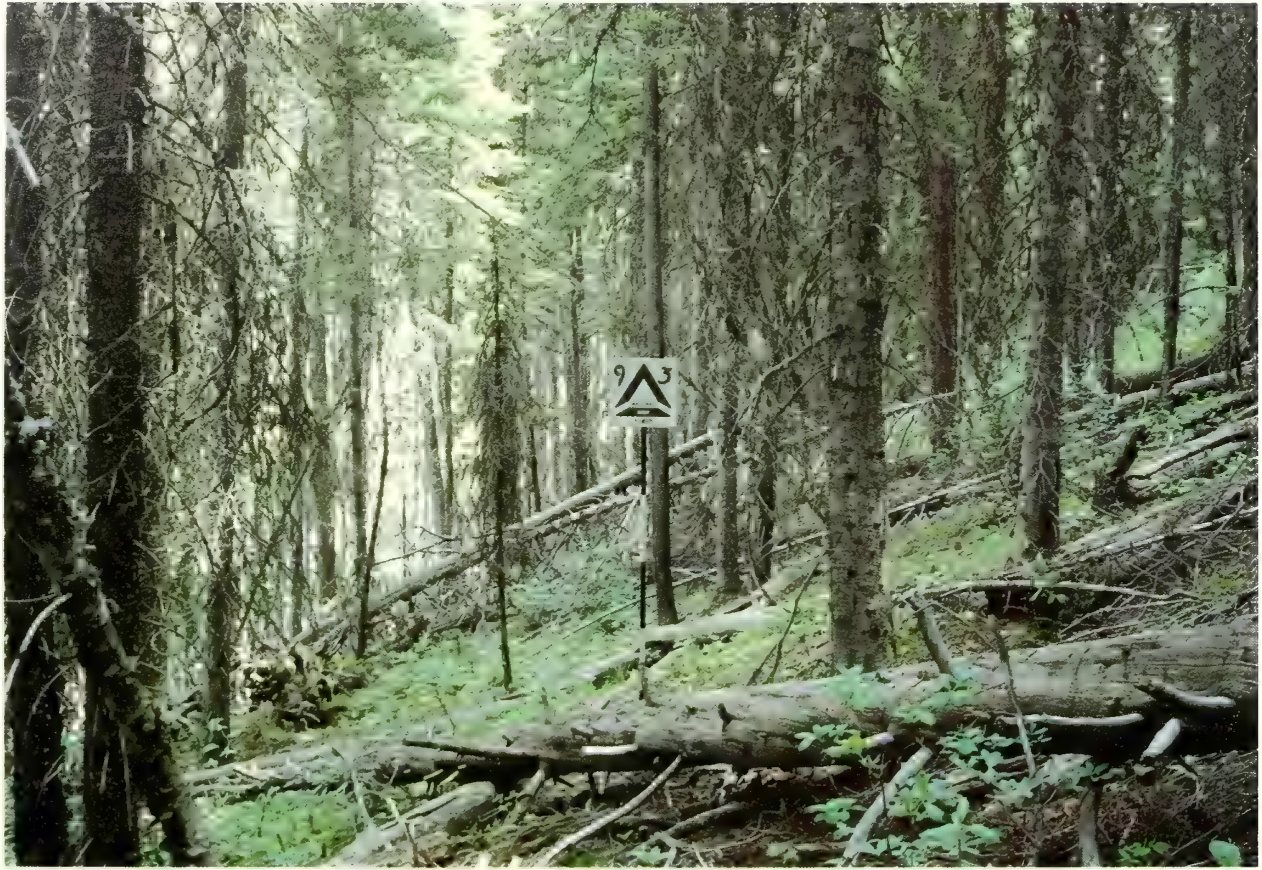
Rate of Spread: high
Intensity: medium
Torching: low
Crowning: medium
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lewis & Clark
Ranger District: White Sulphur Springs
Drainage: Miller Gulch

Photo taken: 8/15/78
By: W. C. Fischer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DATA SHEET

Stand No. 93

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.7	0.16
0.25-1	1.5	0.34
1-3	2.3	0.52
Subtotal 0-3	4.5	1.02
3-6	3.8	0.85
6-10	14.3	3.21
10-20	22.7	5.09
20+	0	0
SUBTOTAL 3+	40.8	9.15
TOTAL	45.3	10.17

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.3 in
5.84 cm

Average diameter, 3+fuels:
7.7 in
19.56 cm

Percent rotten, 3+fuels: 42 %

Volume of **sound** 3+fuels:
1885 ft³/ac
131.9 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	177 yrs
PICO	130 yrs
PICEA	110 yrs

Average slope: 19 %
Aspect: northwest
Elevation 5000 ft 1524 m

Remarks.
Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: low
Torching: low
Crowning: low
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Gillispie Cr.

Photo taken: 6/13/78
By: W. C. Fischer

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DATA SHEET

Stand No. 47

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.8	0.18
0.25-1	2.6	0.58
1-3	6.8	1.52
Subtotal 0-3	10.2	2.28
3-6	4.6	1.03
6-10	4.3	0.96
10-20	27.6	6.19
20+	0	0
SUBTOTAL 3+	36.5	8.18
TOTAL	46.7	10.46

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.6 in
6.60 cm

Average diameter, 3+fuels:
7.0 in
17.78 cm

Percent rotten, 3+fuels: 90 %

Volume of **sound** 3+fuels:
301 ft³/ac
21.1 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	350 yrs
ABLA	78 yrs
PICO	60 yrs

Average slope: 50 %
Aspect: northeast
Elevation: 6000 ft 1829 m

Remarks

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

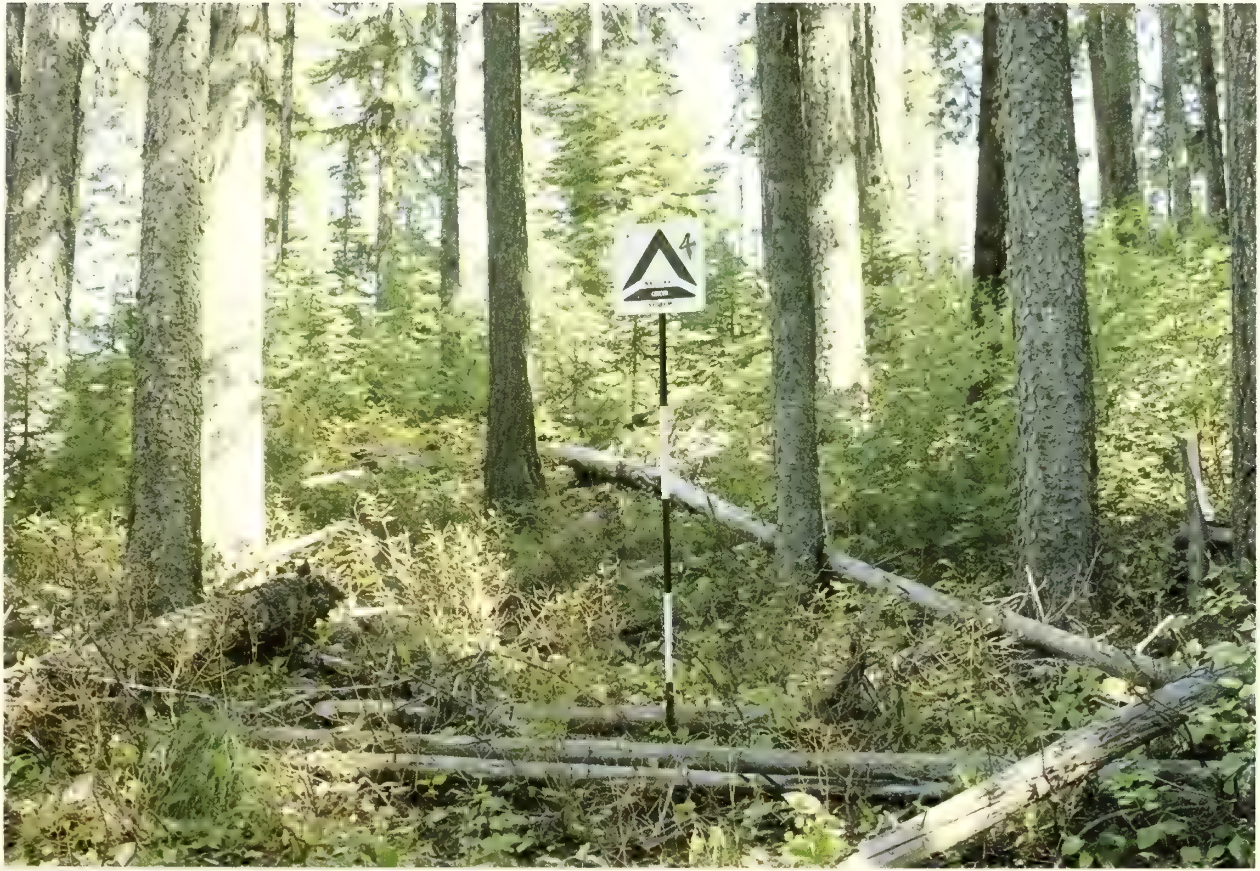
Rate of Spread: high
Intensity: high
Torching: medium
Crowning: medium
Resistance to control: medium

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Gilbert Cr.

Photo taken: 6/24/77
By: W. C. Fischer



FOREST COVER TYPE SAF NO

Stand No

DATA SHEET

Stand No. 4

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.7	0.16
0.25-1	2.3	0.52
1-3	1.8	0.40
Subtotal 0-3	4.8	1.08
3-6	11.2	2.51
6-10	25.6	5.74
10-20	6.3	1.41
20+	0	0
SUBTOTAL 3+	43.1	9.66
TOTAL	47.9	10.74

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 3.2 in

8.18 cm

Average diameter, 3+fuels:

5.5 in

13.97 cm

Percent rotten, 3+fuels: 33 %

Volume of **sound** 3+fuels:

2319 ft^3/ac

162.3 m^3/ha

STAND AND SITE DATA

Age of overstory dominants.

PICEA	150 yrs
LAOC	130 yrs
ABLA	110 yrs

Average slope: 20 %

Aspect: west

Elevation: 4700 ft 1433 m

Remarks: old partial cut

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: low

Crowning: low

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

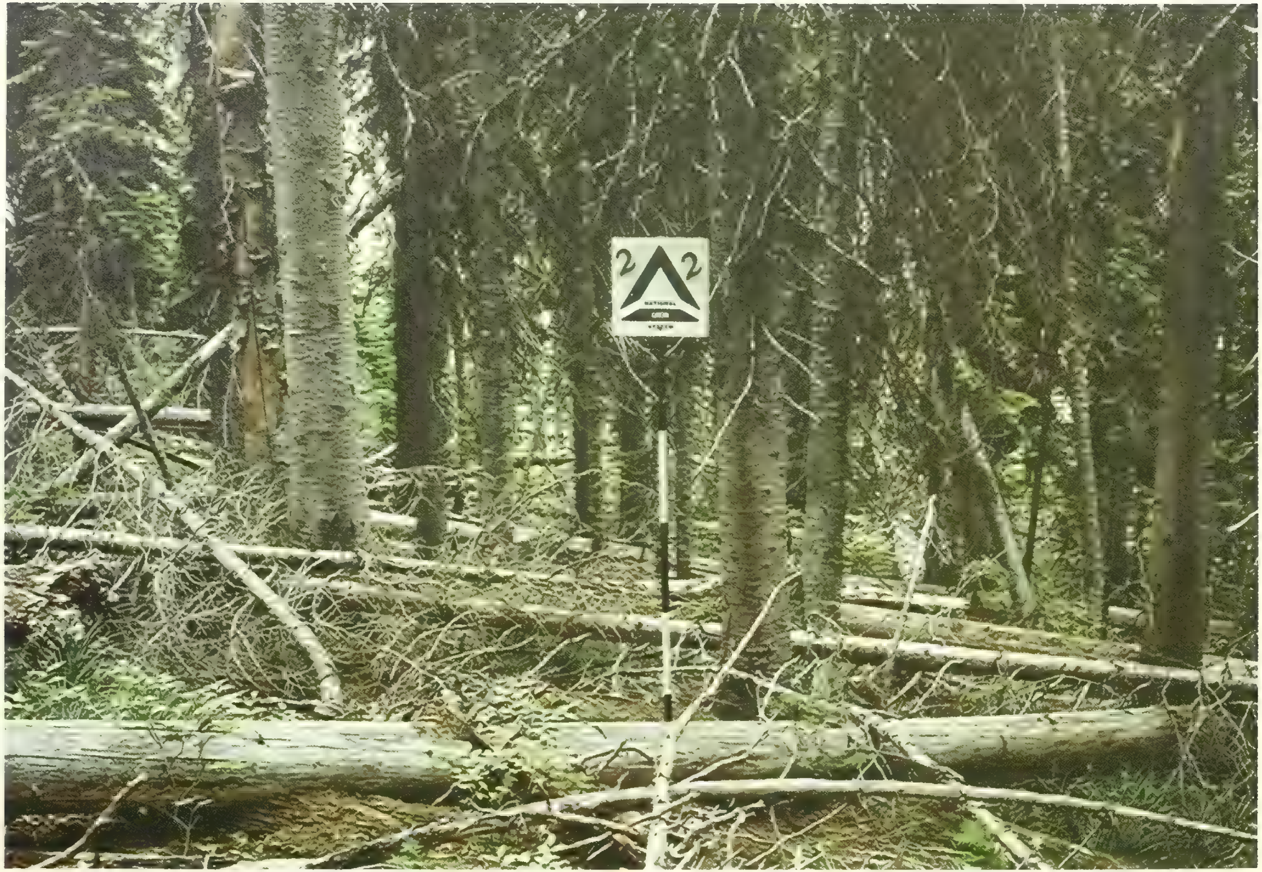
National Forest: Lolo

Ranger District: Missoula

Drainage: Lost Park Cr.

Photo taken: 9/15/76

By: W. C. Fischer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NATIONAL

DATA SHEET

Stand No. 22

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m^2
0-0.25	0.6	0.13
0.25-1	1.7	0.38
1-3	2.4	0.54
Subtotal 0-3	4.7	1.05
3-6	4.1	0.92
6-10	25.6	5.74
10-20	13.6	3.05
20+	0	0
SUBTOTAL 3+	43.3	9.71
TOTAL	48.0	10.76

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 1.7 in
4.32 cm

Average diameter, 3+fuels:
7.1 in
18.03 cm

Percent rotten, 3+fuels: 57 %

Volume of **sound** 3+fuels:
1477 ft^3/ac
103.4 m^3/ha

STAND AND SITE DATA

Age of overstory dominants:
ABLA 174 yrs

Average slope: 20 %
Aspect: east
Elevation: 6100 ft 1859 m

Remarks:
Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90 ° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: high
Torching: high
Crowning: medium
Resistance to control: high

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Lolo
Ranger District: Ninemile
Drainage: Sixmile Cr.

Photo taken: 9/23/76
By: W. C. Fischer

5
1

DATA SHEET

Stand No. 51

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/beargrass-huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.5	0.11
0.25-1	2.7	0.61
1-3	4.1	0.92
Subtotal 0-3	7.3	1.64
3-6	5.8	1.30
6-10	18.6	4.17
10-20	14.7	3.30
20+	2.9	0.65
SUBTOTAL 3+	42.0	9.42
TOTAL	49.3	11.06

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 3.2 in
8.13 cm

Average diameter, 3+fuels:
6.6 in
16.76 cm

Percent rotten, 3+fuels: 33 %

Volume of **sound** 3+fuels:
2250 ft³/ac
157.4 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PSME	210 yrs
ABLA	130 yrs

Average slope: 70 %
Aspect: northeast
Elevation: 5750 ft 1753 m

Remarks:

Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium
Intensity: medium
Torching: medium
Crowning: low
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo
Ranger District: Missoula
Drainage: Gilbert Cr.

Photo taken: 7/6/77
By W. C. Fischer

DATA SHEET

Stand No.

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 630, Subalpine fir/sweetscented bedstraw (ABLA/GATR)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.7	0.16
0.25-1	1.6	0.36
1-3	1.3	0.29
Subtotal 0-3	3.6	0.81
3-6	1.3	0.29
6-10	3.2	0.72
10-20	6.7	1.50
20+	35.8	8.03
SUBTOTAL 3+	47.0	10.54
TOTAL	50.6	11.35

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 4.1 in

10.41 cm

Average diameter, 3+fuels:

10.1 in

25.65 cm

Percent rotten, 3+fuels: 97 %

Volume of **sound** 3+fuels:

122 ft³/ac

8.5 m³/ha

STAND AND SITE DATA

Age of overstory dominants

PICEA	65 yrs
PSME	60 yrs
LAOC	55 yrs
ABLA	44 yrs

Average slope 30 %

Aspect southwest

Elevation 4630 ft 1411 m

Remarks

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: medium

Resistance to control: high

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest: Lolo

Ranger District Missoula

Drainage: Rattlesnake Cr.

Photo taken 7/13/77

By W. C. Fischer

Stand No. 12

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	2.2	0.49
0.25-1	4.3	0.96
1-3	14.1	3.16
Subtotal 0-3	20.6	4.61
3-6	16.2	3.63
6-10	7.5	1.68
10-20	6.7	1.50
20+	0	0
SUBTOTAL 3+	30.4	6.81
TOTAL	51.0	11.42

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
J	12

OTHER FUEL DATA

Average duff depth: 3.0 in

7.62 cm

Average diameter, 3+fuels:

4.6 in

11.68 cm

Percent rotten, 3+fuels: 32 %

Volume of **sound** 3+fuels:

1658 ft³/ac

116.0 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

LAOC	75 yrs
ABLA	75 yrs
PICEA	65 yrs

Average slope 40 %

Aspect north

Elevation 5600 ft 1707 m

Remarks: old thinning slash

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: high

Intensity: high

Torching: high

Crowning: medium

Resistance to control: high

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Lolo

Ranger District: Missoula

Drainage: Cloudburst Cr.

Photo taken: 9/21/76

By W. C. Fischer

2 0

Stand No. 20A

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.5	0.11
0.25-1	1.4	0.31
1-3	3.8	0.85
Subtotal 0-3	5.7	1.27
3-6	16.7	3.74
6-10	22.0	4.93
10-20	6.6	1.48
20+	0	0
SUBTOTAL 3+	45.3	10.15
TOTAL	51.0	11.42

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 3.4 in
8.64 cm

Average diameter, 3+fuels:
4.9 in
12.45 cm

Percent rotten, 3+fuels: 37 %

Volume of **sound** 3+fuels:
2273 ft³/ac
159.0 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
PICEA 165 yrs
PIAL 140 yrs

Average slope: 7 %
Aspect northwest
Elevation 6160 ft 1878 m

Remarks

Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: high
Intensity: high
Torching: high
Crowning: medium
Resistance to control: high

Overall Fire Potential HIGH

STAND LOCATION

National Forest: Helena
Ranger District: Lincoln
Drainage: Cooper Cr.

Photo taken: 7/21/78
By W. C. Fischer

9
4

DATA SHEET

Stand No. 94

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 661, Subalpine fir/twinflower-twinflower phase (ABLA/LIBO-LIBO)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0 0.25	0.5	0.11
0.25 1	1.6	0.36
1 3	2.2	0.49
Subtotal 0 3	4.3	0.96
3 6	8.5	1.91
6 10	30.3	6.79
10 20	7.9	1.77
20+	0	0
SUBTOTAL 3+	46.7	10.47
TOTAL	51.0	11.43

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth 2.7 in
6.68 cm

Average diameter, 3+fuels:
6.4 in
16.26 cm

Percent rotten, 3+fuels: 55 %

Volume of **sound** 3+fuels:
1700 ft³/ac
119.0 m³/ha

STAND AND SITE DATA

Age of overstory dominants

PSME	140 yrs
PICO	103 yrs
PICEA	93 yrs
ABLA	67 yrs

Average slope 25 %
Aspect northeast
Elevation 5100 ft 1554 m

Remarks

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85 90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: medium
Torching: medium
Crowning: medium
Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest Lolo
Ranger District Missoula
Drainage Gillispie Cr.

Photo taken 6/13/78
By W. C. Fischer

FOREST COVER TYPE SAF NO

DATA SHEET

Stand No. 10

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia phase (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	1.1	0.25
0.25-1	3.2	0.72
1-3	2.2	0.49
Subtotal 0-3	6.5	1.46
3-6	12.5	2.80
6-10	28.8	6.46
10-20	11.7	2.62
20+	0	0
SUBTOTAL 3+	53.0	11.88
TOTAL	59.5	13.34

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.7 in
6.86 cm

Average diameter, 3+fuels: 6.0 in
15.24 cm

Percent rotten, 3+fuels: 18 %

Volume of **sound** 3+fuels: 3499 ft³/ac
244.8 m³/ha

STAND AND SITE DATA

Age of overstory dominants:
PICEA 90 yrs
ABLA 80 yrs

Average slope 15 °
Aspect northeast
Elevation 5880 ft 1792 m

Remarks
Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: medium

Torching: medium

Crowning: medium

Resistance to control: medium

Overall Fire Potential MEDIUM

STAND LOCATION

National Forest Lolo

Ranger District Missoula

Drainage Cloudburst Cr.

Photo taken 9/21/76

By W. C. Fischer

FOREST COVER TYPE SAF NO

DATA SHEET

Stand No.

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 670, Subalpine fir/menziesia (ABLA/MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T ac	Weight Kg m²
0-0 25	0.5	0.11
0 25 1	2.8	0.63
1 3	2.6	0.58
Subtotal 0 3	5.9	1.32
3 6	4.5	1.01
6 10	16.3	3.65
10 20	32.8	7.35
20+	3.3	0.74
SUBTOTAL 3+	56.9	12.75
TOTAL	62.8	14.07

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.9 in

7.37 cm

Average diameter, 3+fuels: 7.8 in

19.81 cm

Percent rotten, 3+fuels: 17 %

Volume of **sound** 3+fuels: 3785 ft³/ac

264.8 m³/ha

STAND AND SITE DATA

Age of overstory dominants

PICEA	175 yrs
ABLA	140 yrs

Average slope 50 %

Aspect northeast

Elevation 5860 ft 1786 m

Remarks

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low

Intensity: low

Torching: low

Crowning: low

Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest Lolo

Ranger District Missoula

Drainage Gilbert Cr.

Photo taken 7/6/77

By W. C. Fischer

3
NATIONAL

DATA SHEET

Stand No. 5

FOREST COVER TYPE: SAF NO. 206 , Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 625 , Subalpine fir/queencup beadlily-menziesia phase (ABLA/CLUN-MEFE)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.4	0.09
0.25-1	0.9	0.20
1-3	0.5	0.11
Subtotal 0-3	1.8	0.40
3-6	2.7	0.61
6-10	7.7	1.73
10-20	57.1	12.80
20+	3.3	0.74
SUBTOTAL 3+	70.8	15.88
TOTAL	72.6	16.28

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 4.5 in
11.43 cm

Average diameter, 3+fuels:
10.1 in
25.65 cm

Percent rotten, 3+fuels: 49 %

Volume of **sound** 3+fuels:
2906 ft³/ac
203.3 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICEA	140 yrs
ABLA	140 yrs
PSME	117 yrs

Average slope: 10 %
Aspect northeast
Elevation 4920 ft 1500 m

Remarks

Fire Ecology Group Nine

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15
mi/h wind, 4 weeks since rain

Rate of Spread: low
Intensity: medium
Torching: low
Crowning: low
Resistance to control: low

Overall Fire Potential LOW

STAND LOCATION

National Forest Lolo
Ranger District: Missoula
Drainage: Lost Park Cr.

Photo taken 9/15/76
By S. Cox

3
8

DATA SHEET

FOREST COVER TYPE: SAF NO. 206, Engelmann spruce - subalpine fir

MONTANA HABITAT TYPE: NO. 691, Subalpine fir/beargrass-blue huckleberry phase (ABLA/XETE-VAGL)

DOWN & DEAD WOODY FUEL LOADINGS

Size Class (Inches)	Weight T/ac	Weight Kg/m²
0-0.25	0.2	0.04
0.25-1	1.4	0.31
1-3	5.0	1.12
Subtotal 0-3	6.6	1.47
3-6	11.8	2.65
6-10	47.1	10.56
10-20	11.8	2.65
20+	0	0
SUBTOTAL 3+	70.7	15.86
TOTAL	77.3	17.33

NFDRS FUEL MODEL	STYLIZED FUEL MODEL
G	10

OTHER FUEL DATA

Average duff depth: 2.9 in

7.37 cm

Average diameter, 3+fuels: 6.1 in

15.49 cm

Percent rotten, 3+fuels: 17 %

Volume of **sound** 3+fuels: 4708 ft³/ac

329.4 m³/ha

STAND AND SITE DATA

Age of overstory dominants:

PICEA	200 yrs
ABLA	170 yrs
PICO	117 yrs

Average slope 10 %

Aspect east

Elevation 6380 ft 1945 m

Remarks

Fire Ecology Group Eight

FIRE POTENTIAL RATING

Based on an average bad day:
85-90° temp., 15-20% R.H., 10-15 mi/h wind, 4 weeks since rain

Rate of Spread: medium

Intensity: high

Torching: medium

Crowning: medium

Resistance to control: high

Overall Fire Potential HIGH

STAND LOCATION

National Forest. Lolo

Ranger District Missoula

Drainage Gilbert Cr.

Photo taken 6/23/77

By W. C. Fischer

☆ U.S. GOVERNMENT PRINTING OFFICE: 1981-0-781-749

Fischer, William C.
1981. Photo guide for appraising downed woody fuels in Montana forests: lodgepole pine and Engelmann spruce - subalpine fir cover types. USDA For. Serv. Gen. Tech. Rep. INT-98, 143 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Two series of color photographs show different levels of downed woody material resulting from natural processes in two forest cover types in Montana. Each photo is supplemented by fuel inventory data and potential fire behavior ratings.

KEYWORDS: forest fuels, fire behavior, fire hazard, fuel appraisal

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

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United States
Department of
Agriculture

Forest Service

**Intermountain
Forest and Range
Experiment Station**

General Technical
Report INT-99

March 1981

Clearcutting and Fire in the Larch/Douglas-Fir Forests of Western Montana - A Multifaceted Research Summary

NORBERT V. DeBYLE

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COVER PHOTO:

The square 10-acre units on the relatively gentle slopes at Miller Creek facilitated firing to obtain strong central convection columns on these broadcast burns, illustrated here with a nighttime fire during virtually calm conditions on unit S-8.

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United States
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NORBERT V. DeBYLE

THE AUTHOR

NORBERT V. DeBYLE earned a B.S. in 1953 and M.S. in 1957 from the University of Wisconsin, with major emphasis in soils and forest soils, respectively. In 1962, he was awarded a Ph.D. in forestry from the University of Michigan. Since 1961 he has been employed by the Intermountain Forest and Range Experiment Station, leading watershed management research at Reno, Nev., for 3 years and at Logan, Utah, for 11 years. In his present assignment at Logan with the aspen ecosystem unit, Dr. DeByle continues to study the impacts of wildland management practices and fire on soils and water resources.

ACKNOWLEDGMENTS

This summary report represents contributions from many people. Administrative guidance for the research came from a steering committee composed of Arthur Brackebusch, Samuel S. Evans, Jr., and Charles E. Hardy. Personnel on the Lolo, Flathead, and Coeur d'Alene National Forests facilitated sale preparation and a rigorous harvest and treatment schedule. Ray L. Managhan and Gary L. Cain were responsible for sale administration and prescribed burning. R. C. McConnel surveyed and mapped the soils. William R. Beaufait was the on-the-ground leader and coordinator of the research group, consisting of Rodney A. Norum, William C. Fischer, James K. Brown, Raymond C. Shearer, Robert D. Pfister, L. Jack Lyon, Peter F. Stickney, Norbert V. DeByle, and Paul E. Packer—all scientists of the Intermountain Station; and of Donald F. Adams and Robert Koppe from Washington State University, and Curtis H. Halvorson from USDI Fish and Wildlife Service. Thanks also go to the many technicians involved—especially Patrick F. Hartless, Gerald Voeller, and Bryan D. Williams. Michael A. Marsden and Roger A. McCluskey were responsible for much of the data reduction and analysis.

The Results section is written by the scientists most closely involved with each of the disciplines represented. These scientists and Beaufait deserve more credit, however, for providing much of the material that was incorporated into other chapters of this document. Without their help and without the encouragement and support of Beaufait, Norum, Fischer, and James E. Lotan, this publication would not have been possible.

Constructively critical reviews of this manuscript by Beaufait, Fischer, Halvorson, Koppe, Lotan, Norum, Packer, Pfister, Shearer, Stickney, and Clyde O'Dell are appreciated.

FOREWORD

Increased emphasis on comprehensive land management planning and more flexible fire management policies call for specific, quantified information on how fire affects resource production and the environment. Land managers must be able to predict and interpret biological and ecological responses to prescribed fire and wildfire for use in planning and management of forested ecosystems.

Dr. DeByle's summary report describes the specific effects of prescribed fire and wildfire in the western larch/Douglas-fir forests of western Montana. This study is significant because it considered an array of fire intensities and because it was conducted on an interdisciplinary basis. We are indebted to those who organized and directed such far-sighted effort. Art Brackebusch, Mike Hardy, and Sam Evans, together with Dr. William R. Beaufait, in particular are to be commended for their vision and professional dedication.

The paper should serve both land managers and specialists. It should help land managers make informed decisions in this increasingly complex world. The report will make managers more aware of possible consequences of clearcutting and burning and more capable of measuring these consequences than in earlier times.

Forestry specialists, certified silviculturists for example, will also benefit from the specific information useful in writing prescriptions and in assessing environmental impacts.

It is a particularly difficult task to write an integrated summary of an interdisciplinary study such as the one conducted at Miller Creek and Newman Ridge. Dr. DeByle is to be commended for his role in bringing us this paper.

JAMES E. LOTAN
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Fire Effects Program
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Missoula, Montana

RESEARCH SUMMARY

Logging slash on 73 clearcuts in the western larch/Douglas-fir forest of western Montana was broadcast burned over a wide range of environmental conditions. A broad array of fire intensities and effects was achieved. A severe wildfire was also evaluated and compared to the prescribed fires. Fire effectiveness, especially for removing the duff layer, was measured and related to preburn conditions, fuel loads, and fire intensity. The effects of these treatments on air quality, forest regeneration, vegetative recovery and development, small mammal populations, soil physical and chemical parameters, and runoff and erosion were measured and analyzed.

Fine fuels contribute most to fire spread and intensity. Water content of fine fuels should be within 10 to 17 percent for safe and effective burning. If fuels are uniformly distributed, measurements of duff depth and of the water content of its lower half permit prediction of the amount of an area that will burn bare to mineral soil. Fire intensity influenced the height of smoke columns most, pushing some plumes 8,000 feet above the mixing depth. The smoke contained about 30 pounds of particulate matter for each ton of fuel consumed. After a good seed crop, conifer seed distribution on small (<15 acres) clearcuts was adequate, and germination was good on sites with one-half inch or less of residual duff. Seedling loss from summer drought was severe on south slopes, where practices to provide additional shade are recommended. Herbaceous cover increased rapidly after fire, peaking by the second or third postburn year. Shrubs did not predominate until at least the sixth year. Deer mice, chipmunks, and red-backed voles consume significant quantities of seed from conifers. Red-backed voles were most common in old-growth timber but virtually disappeared after clearcutting and burning. Deer mouse populations increased dramatically after intense fires. The treatments temporarily impaired soil protection and increased overland flow and erosion. However, vegetative recovery on all but the south slopes returned conditions to near prelogging status within 5 years. There was a flush of nutrients in overland flow and sediment during the first postfire year. The ash-duff layer lost nutrients and the surface mineral soil gained nutrients during the first 2 years.

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Beaufait viewing the logging operation at Newman Ridge in 1968.

INTRODUCTION

Broadcast burning of logging slash to reduce wildfire hazard and to prepare the site for planting began as early as 1910 in the western white pine type (LeBarron 1957). Today the use of prescribed fire is a well-established technique in Northern Rocky Mountain forests (Olson and Fahnestock 1955; Roe and others 1971). Although the use of fire to accomplish land management objectives in the West has been practiced for decades, the research described herein is the first known attempt to enlist several disciplines in an investigation of the effects of many broadcast fires, burned over a wide range of fuel and weather conditions, in the logging slash of western conifers.

This multidisciplinary research commenced in 1966 in the western larch/Douglas-fir forests of northwestern Montana by a team of scientists working in close cooperation with land managers. The effects of clearcutting, ground-lead skidding, and subsequent broadcast burning of the logging slash in these old-growth forests were evaluated from several perspectives. Fire behavior and amount of fuel and duff consumed were related to fuel and weather variables by fire scientists; smoke production and dispersion were studied by air quality engineers; seedbed preparation and establishment and growth of conifer seedlings were measured by silviculturists; successional development and amount of cover afforded by vegetation growing on the burns were traced through several years by plant ecologists; numbers and species of small mammals on treated and on control areas were quantified by a wildlife biologist; and physical and chemical impacts on soil and on runoff waters were determined by watershed and soil scientists. Most of the results within each of these fields have been published (appendix C lists publications). In this report, however, results of all disciplines are summarized and then discussed as an integrated body of research, with emphasis on findings of particular value to the resource manager.

Background

Fire is one of the driving forces in the Northern Rocky Mountain conifer forest ecosystem. Indeed, some forest types are considered to be fire dependent (Habeck and Mutch 1973). The western larch/Douglas-fir type is one of these. It is a seral type, usually growing as even-aged stands following wildfire. Fire kills some or all of the standing crop, opens up the forest, and creates a mineral soil seedbed, allowing tree regeneration. Hence, fire can be considered a natural part of this forest environment (Wellner 1970). This vegetation-soil complex has developed over thousands of years, with fire periodically perturbing the system.

During this century the value of these forests as a source of wood for our society was realized. This value has resulted in these lands being protected, when possible, from wildfire. Clearcutting has been a common method of harvesting timber. After harvesting, prescribed burning often is used to prepare mineral soil seedbeds and reduce the wildfire hazard created by logging residue (Steele and Beaufait 1969). Thus, to the extent possible, man has mimicked the natural role of wildfire in his management of this forest type.

Between 250,000 and 300,000 acres (100 000 to 120 000 ha) of forest are harvested annually in the Northern Rocky Mountain region of the United States. Most of these harvested acres require treatment to assure adequate natural regeneration or, alternatively, to prepare the site for planting. Resource managers are faced with the problem of adequately regenerating these stands with desirable species at a reasonable cost. Moreover, sites to be treated must be protected from wildfire, watershed damage, and potential reduction in soil productivity. Also, of increasing importance, atmospheric quality must be maintained in conformance with State and Federal air standards. Water quality, aquatic habitat, wildlife habitat, and amenity values must be maintained, too.

Of the several techniques for reducing fire hazard and preparing the clearcut for regeneration, prescribed fire is usually the most economical. Because it is easy to control and relatively inexpensive, dozer piling of logging debris and burning of these piles after autumn rains thoroughly wet the forest earlier was the most common use of prescribed fire in this region. As the technique was developed and accepted, and with increasing concern about equipment and energy costs, watershed protection, soil productivity, air quality, and natural amenity values, the use of broadcast burning of logging slash became widely applied. Approximately 10,000 acres (4 000 ha) of clearcut forest land are broadcast burned annually in this region. This represents most of the acreage now clearcut each year.

Based on interviews with foresters throughout the Intermountain West, Beaufait (1966b) characterized a successful broadcast burn as one that:

(1) consumed the duff to the extent of exposing mineral soil on 50 percent or more of the area burned, and (2) consumed all woody material up to about 6 inches in diameter. Prescribed broadcast burns have not always accomplished these objectives. As a tool for preparing sites for future crops, prescribed fire was found to produce erratic results in many areas (e.g., not enough seedlings in spruce forest types, too many in larch and lodgepole pine). Wikstrom and Alley (1967) found a large, unexplained variation in slash disposal and burning costs. It became important to relate such variation to silvicultural practices. Also, the practice of clearcutting coupled with the short fall burning period resulted in an increasing backlog of acres requiring treatment.

Probably the most important reason for prescribed burning failures is the variable nature of fire itself. Fire can burn over an area in an infinite number of ways. Intensity depends on fuel volume and moisture content as well as environmental conditions. Thus, fire is not a single treatment but rather a number of possible treatments. To be successful, the prescription and execution of a fire must be specific to a fuel bed, its moisture condition, and to at least one well-defined management objective (Fischer 1978).

Prescribed fires usually are conducted during safe burning conditions for the convenience of the responsible organization. Concern, unfortunately, is often centered on the fact of treatment rather than on the quality of treatment. Furthermore, emphasis is often placed on burning to reduce wildfire hazard, seedbed preparation being an expected side benefit. Although the wildfire hazard may be satisfactorily reduced by burning only the fine fuels, site preparation may not occur unless the duff also burns.

The need to improve the quality of prescribed burning accomplishment was recognized by land managers and research scientists alike. Consequently, the Northern Region and the Intermountain Forest and Range Experiment Station of the Forest Service jointly supported this study of prescribed fire and its use in forest management.

Development of This Research

Beaufait's survey (1966b) of prescribed burning in the Intermountain West provided insight into management problems. The survey indicated that greater use of broadcast burning and extension of the burning season into the spring and summer period would be necessary if forest management objectives were to be met. The increasingly steep sites being logged and the large acreages annually being cut precluded complete reliance upon the conventional method of "pile and then burn in the autumn" for meeting these objectives. Also, new personnel would have to be trained to accomplish the burning.

A need for better guidelines in the use of prescribed fire, particularly broadcast slash burning, as a silvicultural tool was recognized. After review of prescribed fire from both administrative and research viewpoints, a prospectus was written outlining participation of all concerned disciplines in a series of studies to be superimposed on a basic design to be developed by scientists at the Northern Forest Fire Laboratory. This prospectus was implemented in 1966. Highest priority was assigned to the western larch/interior Douglas-fir forest type growing on sites where subalpine fir is climax in the Northern Rocky Mountain region. In the autumn of that year the Miller Creek block, with some 60 cutting units, was laid out on the Flathead National Forest. After research was underway here, a replication was established in 1968 on Newman Ridge on the Lolo National Forest. (For simplicity and ease of reading, these two cutting blocks are usually referred to as Miller or Newman, respectively, throughout the remainder of this paper.)

Fortunately, fire research techniques developed over recent years permitted successful instrumentation of, and data gathering from, the chosen study blocks at Miller and Newman. Recent research attention to the nature of fuels and the behavior and intensity of fire itself was especially important at this point in time.

Measurements of slash fuels and the behavior of slash fires made by Olson and Fahnestock (1955), Fahnestock (1960), and Fahnestock and Dieterich (1962) provided a basis for quantifying potential energy sources in the use of fire for silvicultural and other land management purposes. Other forest fire researchers began characterizing natural forest fuel beds by the amount of work accomplished by prescribed fires. Using Byram's (1959) equations for energy release rate Van Wagner (1965) compared the effects of burning at four fuel levels. He applied head fire intensity data to tree crown and stem damage seedbed preparation, and subsequent regeneration. As fire intensity increased, both mineral soil exposure and seedling success improved. Similar results were reported by Buckman (1962, 1964 and by Beaufait (1960, 1962). More recently laboratory studies of fire behavior in forest fuels developed a foundation for characterizing fires under natural conditions. Building upon the work of Thomas (1958, 1963), Rothermel and Anderson (1966) modeled fuel beds and stressed the importance of energy release rate for describing fire intensity and behavior.

Between 1963 and 1965, a series of 2- to 4-acre (approximately 1 - to 2-ha) areas were inventoried and broadcast burned in Douglas-fir slash on the University of Montana's Lubrecht Experimental Forest. This was perhaps most applicable to the planned research at Miller and Newman. These tests provided: (1) a quantitative comparison of site and early vegetative succession after replicated fires in two spring and two autumn seasons, and (2) successful instrumentation for evaluating burn quality, fire intensity and spread, fuel volume and moisture content, and ignition and control methods (Steele 1964; Steele and Beaufait 1969).

Objectives

The principal purpose for this research was to develop criteria by which prescribed broadcast fires in logging slash could be scheduled to best meet site preparation, hazard reduction, and other management goals. Objectives of the fire research phase were: (1) correlate a wide range of fuel and weather conditions with amount of duff reduction and mineral soil exposure; (2) predict prescribed fire smoke column height from fuel conditions and environmental factors; (3) provide a design and field layout upon which studies by cooperating scientists from other disciplines could be superimposed.

Fire effects literature usually contains a grossly inadequate quantification of the fires involved. Fire intensity is often characterized as being "high" or "low" based only upon the investigator's experience. This study design provided an unparalleled opportunity to correlate fire effects with quantified fires conducted over a wide range of fuel and environmental conditions. Taking advantage of this opportunity, studies with the following goals were conducted:

The air quality and smoke management study objectives were (1) to determine the range of combustion product emissions from a series of fuel moistures and meteorological conditions, and (2) to monitor the movement and dispersal of these emissions.

The overall silvicultural research objective was to determine how regeneration of selected conifers was influenced by seedbed condition and other site factors following prescribed fires in clearcuts. These results were contrasted with nearby uncut areas burned by wildfire or slashed but unburned clearcuts.

The plant ecology objective was to describe in quantitative terms the development of seral forest communities following the clearcutting-burning treatment, and to determine the influence of prelogging vegetation and fire on vegetal development patterns.

Small mammal populations were studied to (1) determine animal species composition and relative abundance on uncut and clearcut/burned areas, and (2) to relate mammal succession patterns to plant succession after clearcutting and broadcast burning.

The watershed and soils objectives were: (1) to determine which vegetal, soil, and topographic factors affect overland flow and soil erosion, (2) to measure the effect of varying intensities of broadcast burning on overland flow and erosion, (3) to develop means for predicting expected overland flow and erosion after burning under selected prescribed conditions, and (4) to determine the changes in soil chemistry and fertility, the quality and nutrient content of overland flow, and the plant nutrient losses from these sites as a result of the clearcutting and quantified broadcast burning treatments.

A series of north-facing units at Miller that have been logged; three units (N-5, -11, and -12) were burned the season prior to this photograph. (Washington State University photo)

AREA AND STUDY DESCRIPTIONS

Site Description

The Miller block is on the Miller Creek and Martin Creek drainage near Olney, Mont. (48°31' N. latitude, 114°43' W. longitude); the Newman block is approximately 100 miles (160 km) southwest, on Newman Ridge between Two Mile Creek and Ward Creek, near St. Regis, Mont. (47°17' N. latitude, 115°17' W. longitude) (fig. 1.). A combined total of 76 treatment units were located on both blocks—sixty 10-acre (4-ha) units at Miller; 16 units, ranging from 20 to 58 acres (8-24 ha), at Newman (figs. 2 and 3).

The elevation at Miller ranges from 4,200 t 5,000 feet (1280-1524 m). Slopes average 2 percent and range from 9 to 35 percent. Soils hav developed in glacial till from the argillites an quartzites of the Wallace (Belt) formation and ar mantled with a thin layer of loess. They belong t the Sherlock soil series and, for the most part, ar Andic Cryoboralfs having an unincorporated su face organic horizon from 1 to 3 inches (2-8 cn thick. The surface 1/2 to 1 inch (1-3 cm) of minera soil is silt loam of single-grain structure (30 pe cent sand, 56 percent silt, 14 percent clay). Thi overlies a foot of gravelly loam with a weak block structure, beneath which is very stony loam to depth of at least 6 feet (2 m).

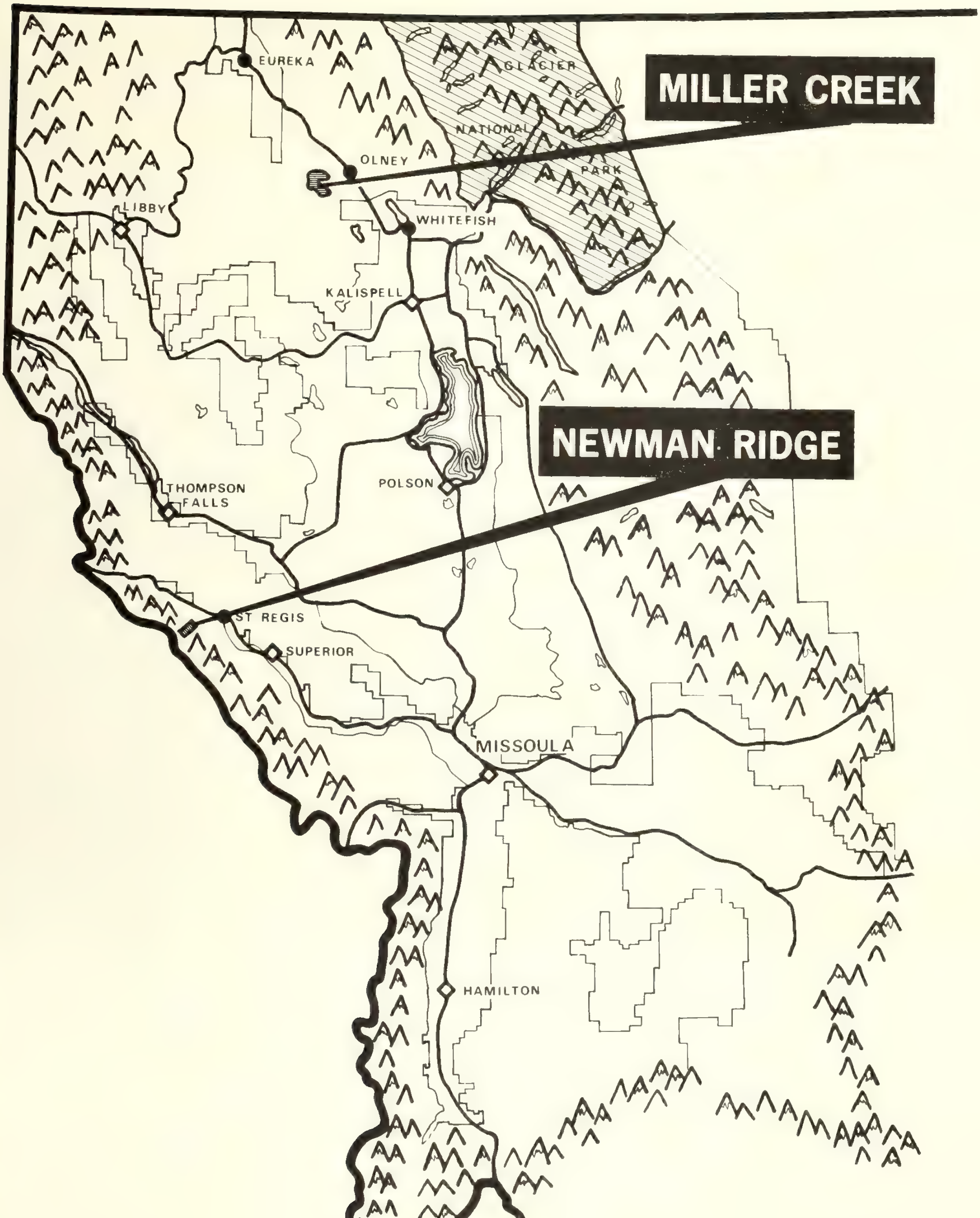

Figure 1.—Location of Miller and Newman study sites in northwestern Montana.

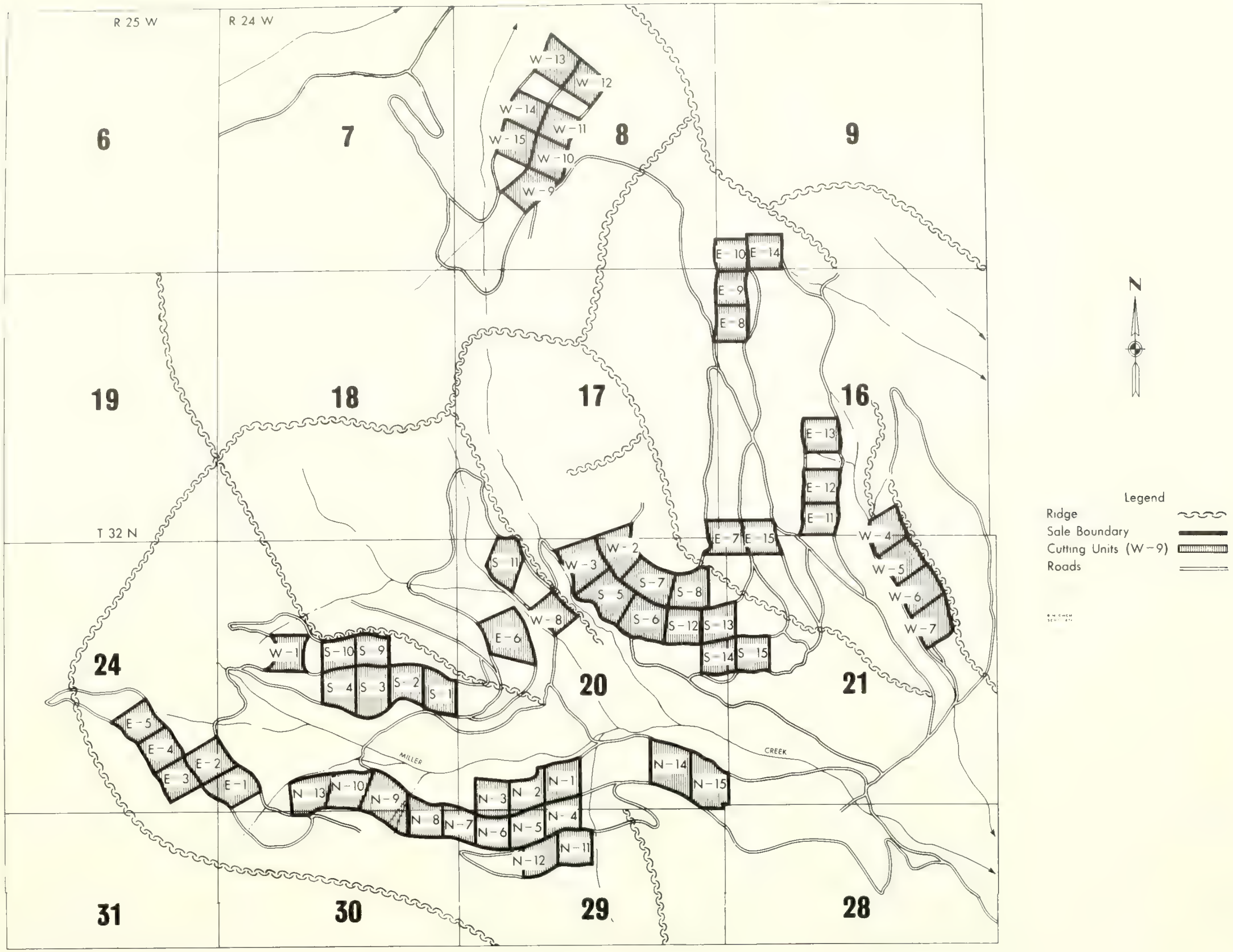

Figure 2.—Layout of 10-acre units at Miller.

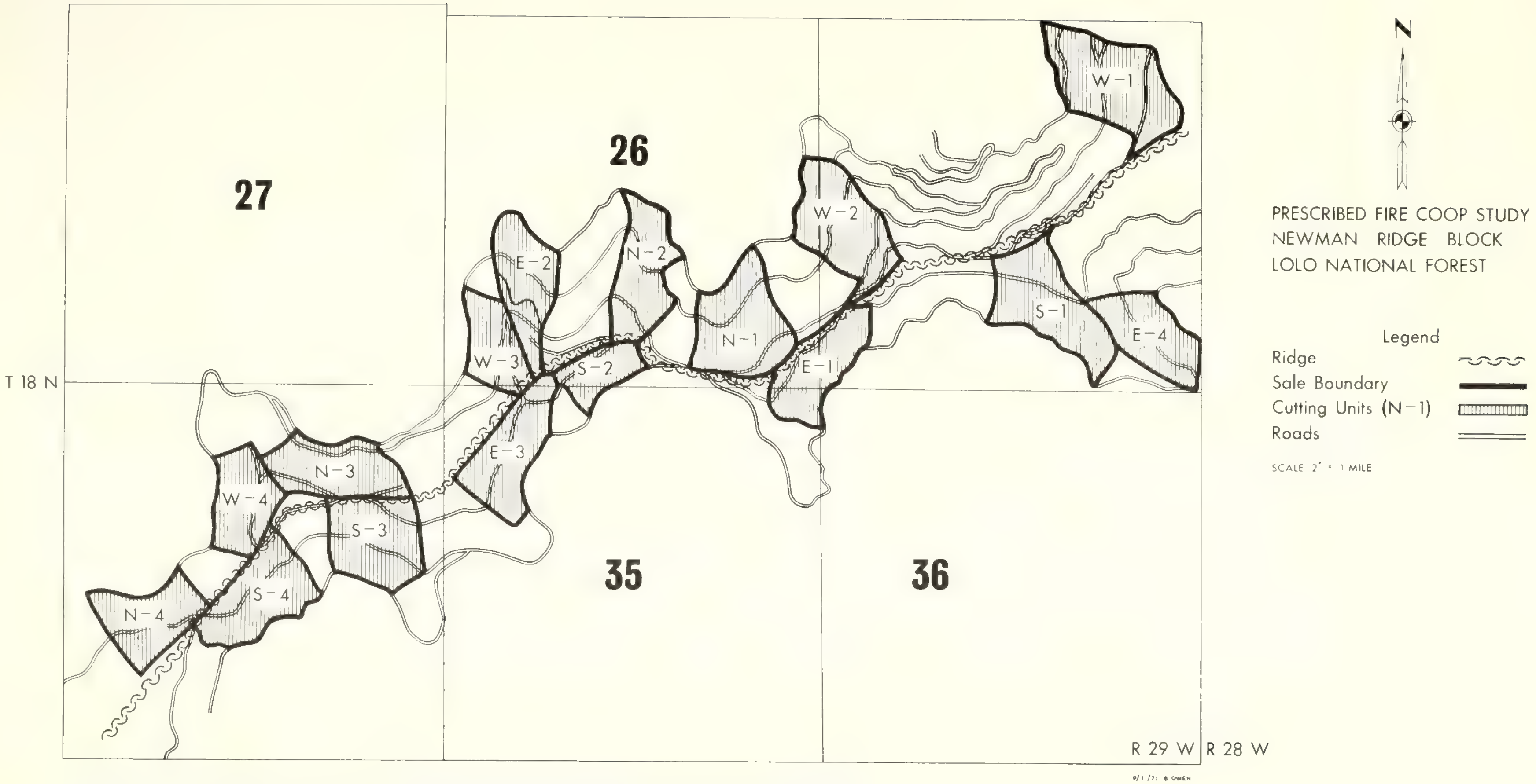

Figure 3.—Layout of the 16 units along both sides of Newman Ridge.

The Newman study area is slightly higher; elevations range from 4,400 to 5,400 feet (1 341-1 646 m) and much steeper (mean slope of 55 percent, ranging from 44 to 76 percent) than Miller. Soils have developed in place or in colluvium from argillites and quartzites of the Belt formation. The surficial loess deposit at Miller is 1/2 to 2½ inches (1-6 cm) thick; on Newman it is 2 to 3 inches (5-8 cm) thick. Ash from the Mt. Mazama and Glacier Peak volcanic eruptions occurs in this loess (Fryxell 1965); the remainder of the deposit probably comes from the Palouse region in eastern Washington. The texture of the surface 2 inches (5 cm) of soil on Newman is silt loam (29 percent sand, 58 percent silt, and 13 percent clay). These soils belong to the Craddock series and classify as Andic Cryochrepts.

Both the Miller and Newman areas charactistically have long, cool, wet winters and short, dry summers. Annual precipitation averages about 25 inches (64 cm) at Miller and nearly 40 inches (102 cm) at Newman; approximately two-thirds falls as snow. Although high-intensity summer rainstorms occasionally occur, most rain falls at low intensities from Pacific maritime frontal systems. The most rainfall comes during April, May, and June, the months when snowmelt runoff is greatest. These are humid watershed lands, which yield more than 10 inches (25 cm) of streamflow annually, nearly all as yearlong seepage flow (Packer 1959). When plant cover is sufficient, only a small part of the annual precipitation becomes overland flow. Most of it contributes to seepage flow or is stored in the soil mantle and thus reduces soil water deficits created by evapotranspiration.

The vegetation on both blocks was classified according to forest cover type (Society of American Foresters 1954) and habitat type (Pfister and others 1977). The cover types identified were: larch/Douglas-fir, grand fir/larch/Douglas-fir, ponderosa pine/larch/Douglas-fir, lodgepole pine, and Engelmann spruce/subalpine fire. The larch/Douglas-fir type occupied well over 50 percent of the area. With typical variation due to exposure, Miller timber volumes were almost evenly divided among western larch, interior Douglas-fir, and Engelmann spruce. Newman produced little spruce, but had a greater variety of species, including some ponderosa pine and western white pine. Lodgepole pine and true firs had significant volumes in both blocks. The Miller stands were 200 to 250 years old, those on Newman 180 to 200 years old. The volume of commercial timber harvested from these blocks is summarized in table 1.

Table 1.—Commercial timber volumes harvested (Scribner Decimal C)

Species	Miller Creek (641 acres)		Newman Ridge (526 acres)	
	M bd.ft./ acre	Percent of total	M bd.ft./ acre	Percent of total
Larch	6.4	25.7	5.1	26.4
Douglas-fir	7.5	30.6	6.5	33.6
True fir	1.6	6.5	1.4	7.3
Spruce	7.6	31.1	0.6	2.8
Lodgepole pine	1.5	6.2	3.3	16.9
Ponderosa pine	0	0	1.7	8.8
White pine	0	0	.6	2.8
Cedar	0	0	.3	1.4
Total	24.6	100.0	19.5	100.0

The Miller block, with a relatively uniform, cool, moist environment, consists largely of only one habitat type (h.t.), *Abies lasiocarpa/Clintonia uniflora.* Three phases of this h.t. are represented: *Menziesia ferruginea* phase on the colder middle and upper north and east slopes, *Xerophyllum tenax* phase on the drier south and west aspects, and *Clintonia uniflora* phase on the remaining sites. Cool, moist stream bottoms were mapped as *Thuja plicata/Clintonia uniflora* h.t. (fig. 4).

In contrast, on Newman Ridge seven distinct habitat types were identified, from a warm and dry *Pseudotsuga/Physocarpus* h.t. to a cool and moist *Thuja plicata/Clintonia uniflora* h.t., *Menziesia ferruginea* phase. This variety of types was reflected in the broad vegetal diversity which occurred across this ridge. The seven types represented were: *Abies grandis/Clintonia uniflora* h.t., on concave east, northwest, and protected south-facing slopes; *Abies grandis/Xerophyllum tenax* h.t. on upper west-facing slopes; *Thuja plicata/ Clintonia uniflora* h.t., *Menziesia ferruginea* phase on concave north and northeast aspects; *Pseudotsuga menziesii/Vaccinium globulare* h.t., *Xerophyllum tenax* phase on upper south-facing slopes; *Pseudotsuga menziesii/Physocarpus malvaceus* h.t., *Physocarpus malvaceus* phase on convex southwest slopes; *Abies lasiocarpa/Clintonia uniflora* h.t., *Menziesia ferruginea* phase on north slopes along the ridge lines; and *Abies lasiocarpa/Xerophyllum tenax* h.t., *Vaccinium globulare* phase on south slopes along the ridge line (fig. 5).

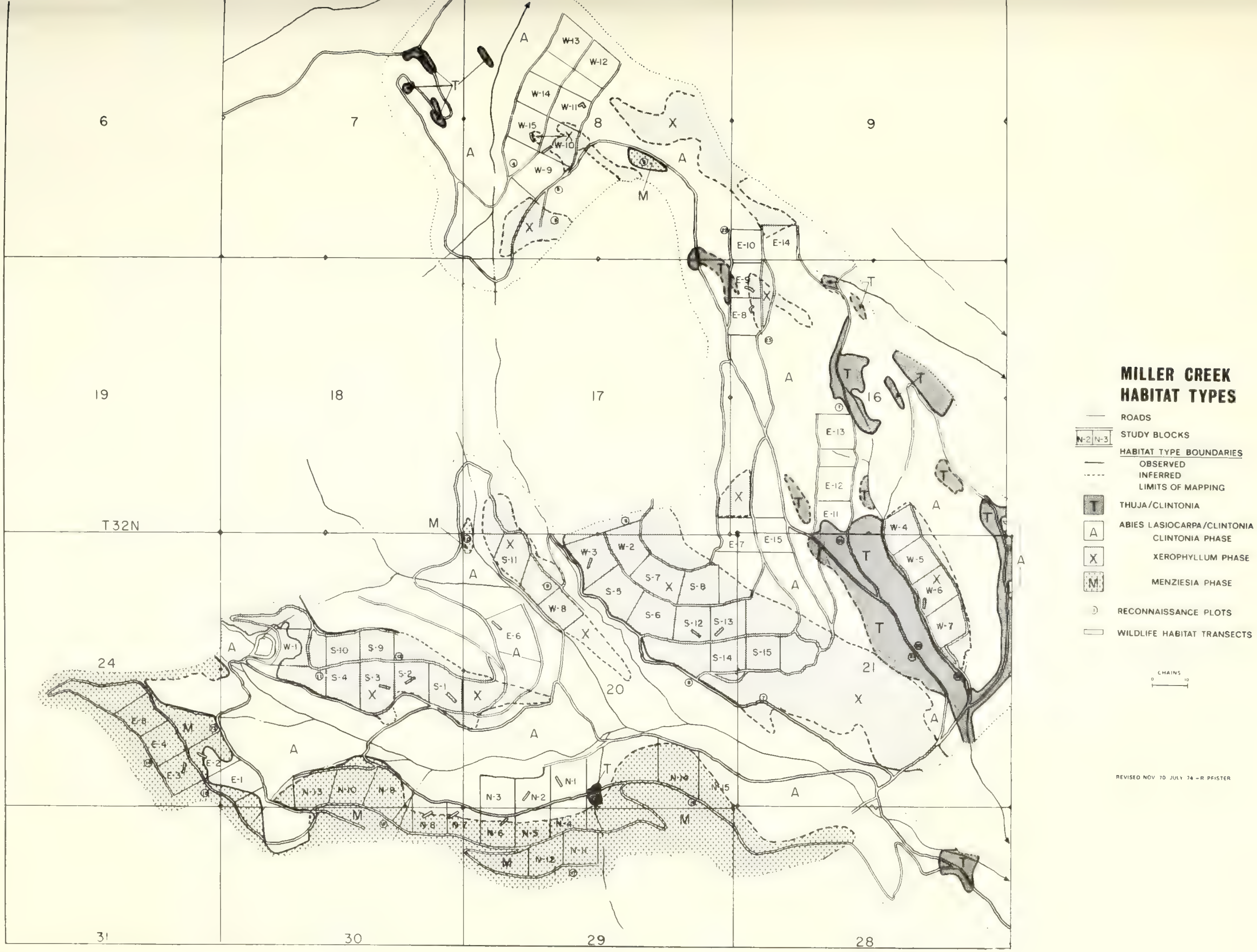

Figure 4.—Habitat types at Miller.

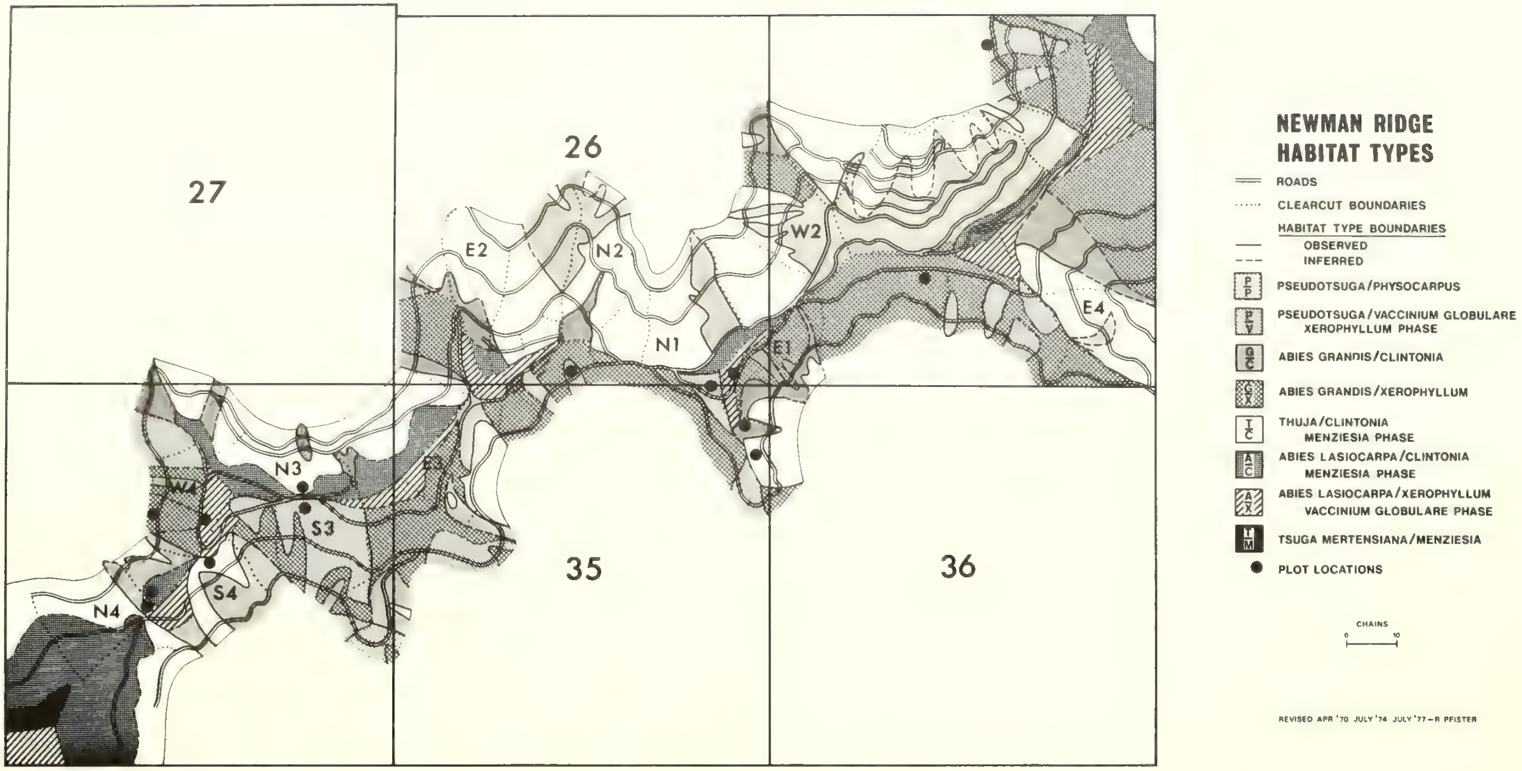
NEWMAN RIDGE
HABITAT TYPES
ROADS
CLEARCUT BOUNDARIES
HABITAT TYPE BOUNDARIES
OBSERVED
INFERRED
PSEUDOTSUGA/PHYSOCARPUS
PSEUDOTSUGA/VACCINIUM GLOBULARE XEROPHYLLUM PHASE
ABIES GRANDIS/CLINTONIA
ABIES GRANDIS/XEROPHYLLUM
THUJA/CLINTONIA MENZIESIA PHASE
ABIES LASIOCARPA/CLINTONIA MENZIESIA PHASE
ABIES LASIOCARPA/XEROPHYLLUM VACCINIUM GLOBULARE PHASE
TSUGA MERTENSIANA/MENZIESIA
PLOT LOCATIONS
CHAINS
0
10
REVISED APR '70 JULY '74 JULY '77 – R PFISTER
27
26
35
36
E2
N2
W2
N1
E1
E4
N3
W4
S3
E3
S4
N4

Figure 5.—Habitat types at Newman.

Preburn fuel loads, excluding duff, varied from 60 to 165 tons/acre (14-37 kg/m^2) among individual units. Miller units supported slightly greater slash loadings than those at Newman—114 tons/acre compared to 104 tons/acre (25 kg/m^2 vs. 23 kg/m^2). Size distribution was quite similar. Approximately 88 percent of the slash fuel weight was greater than 4 inches (10 cm) in diameter; 10 percent was 0.4 to 4 inches (1-10 cm) in diameter; and 1 percent each was twigs and needles (Beaufait and others 1977). Duff weight on individual units varied between 4 and 50 tons/acre (0.90 and 11 kg/m^2) at Miller and between 15 and 29 tons/acre (3 and 7 kg/m^2) at Newman. Average duff weight at Miller was 26 tons/acre (5.9 kg/m^2) compared to 23 tons/acre (5.1 inches (5.45 cm) at Miller and 2.05 inches (5.22 cm) at Newman (Beaufait and others 1977).

Study Design

The 60 units at Miller Creek and the 16 at Newman Ridge were each laid out in an orthogonal design, with equal numbers generally facing each of the four cardinal aspects.

A square plot, 2½ acres (ca. 1 ha) in size, in the center of each Miller unit was used for much of the sampling. Three similar plots were laid out in each of the Newman units (fig. 6).

The study plan called for an equal number of fires, in similar fuel loadings, on all aspects, in the spring, summer, and autumn for 2 years (1967 and 1968) at Miller and 1 year (1969) at Newman (Beaufait and others 1977). The ideal of complete orthogonality was not achieved. A wildfire in August 1967 at Miller burned several south-, east-, and west-facing units, creating an imbalance in the original design. Also, concern for fire control further compromised the design: units with heavy fuel loading were burned under wetter conditions than those with light loading. A total of 73 sample plots in 55 different units were burned and the data used in subsequent analyses. Of these, 11 sample plots were burned in the spring, 51 in the summer, and 11 during the autumn. The treatment record over the 3 years probably represents the realistic range of prescribed burning opportunities in the Northern Rocky Mountains.

Methods

The design required that fuel loads be spread as uniformly as possible across each unit, which also enhanced fire spread if burning conditions were less than ideal. To accomplish this, directional felling and double-drum jammer skidding was used. The jammer roads were spaced at least 600 feet (183 m) apart. No machine operation was allowed within the 2.5-acre sample plots. After felling and skidding were completed, a slash crew dropped all remaining stems, thus enhancing fuel bed uniformity wherever possible. Slash was allowed to dry and weather before burning. Average slash curing time was 9 months, but ranged from less than 2 to almost 18 months on the burned units from which data to meet the objectives of this research were gathered. Eight units not burned remain as controls for long-term comparison of treatments. A few units were burned up to 3 years after harvest. Four units at Miller were not logged before being swept by the August 1967 wildfire. Two of these on a south slope, adjacent to slashed units that were burned at the same time, remain a valuable comparison of fire in standing timber versus fire in logging slash.

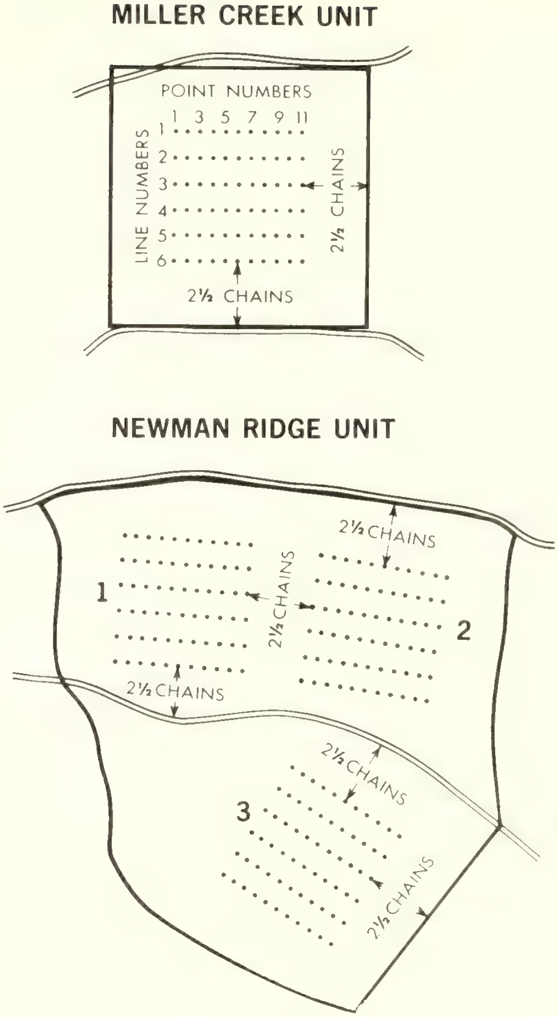

Figure 6.—Plot layout and sampling point locations on typical units.

The sampled plots were burned over a range of conditions during the years of 1967-1970. The fuel treatment schedule and tabulated burning conditions may be found in Beaufait and others (1977).

Anticipated fire behavior was the main consideration in determining if a unit was ready to burn. Fuel moisture was to be within a range where the fire could be expected to burn the entire unit and weather had to be favorable enough to permit containing the fire within the designated unit. Fuel water content and weather were continuously monitored to evaluate a unit's readiness to burn. Weather stations were operated throughout the snow-free seasons at Miller and Newman close to the clearcut units. Weather records were used to compute fire-danger buildup index (USDA Forest Service 1964) during the June through October seasons, when fires were conducted at Miller in 1967 and 1968 and Newman in 1969. In addition, to measure annual precipitation for watershed research, a storage gage was maintained at each study site for several years. As part of the silviculture research, three additional weather stations were operated at Newman Ridge from 1969 through 1974. These measured air temperature, relative humidity, and amount and direction of air movement on north- and south-facing clearcuts and the intervening ridge from June to October of each year.

To attain the fire research objectives, each unit was sampled to determine depth and weight of duff; amount, size, and kind of fuel potentially available; water contents of duff, fuel, and soil at fire time; and amount of heat experienced during the fires.

The duff was quantified by weighing a large number of cylindrical duff samples of known volume and depth. Ratios of dry weight to depth were used to develop equations for predicting duff weight from preburn and postburn measurements of duff depth. The weight of duff per unit of depth was found to be different for different exposures (Beaufait and others 1977). Duff depths then were measured both before and after burning on at least 72 points on each study plot.

The amount of dead and down woody slash fuels was measured on 66 points on each plot using a planar intersect sampling scheme, with 3P subsampling as reported by Beaufait and others (1974). This method is similar to that described by Brown (1974), and could be simulated by following Brown's method of inventorying down woody material. The fuel loadings are tabulated in detail by size class and fuel type in Beaufait and others (1977).

Fuels, duff, and surface mineral soil were sampled on each site immediately prior to burning and their water content determined. A combination of ovendrying and titrimetric methods was used to measure the water contents.

Weight loss from 36 water can analogs per study plot (Beaufait 1966a) was used to sample heat pulse to the site during each fire. These analogs indicate the total amount of heat experienced at the point of measurement; they do not truly measure fire intensity in terms of energy release rate on an area. The amount of water lost from these analogs was significantly related to the water content of the upper half of the duff layer and to buildup index as reported by Beaufait and others (1977). Water can analogs are of little use to managers, but do serve a purpose in fire research by indicating relative intensity among fires.

The air quality and smoke management phase of this research was accomplished by employing three methods: (1) Continuous measurement of air quality was made at ground level at five points within 30 miles (48 km) of the burned units. (2) Smoke and carbon dioxide concentrations, elevations, and drift patterns were measured from selected fires with an aircraft. (3) Samples of slash and duff fuel were analyzed and were burned under controlled conditions in the laboratory and the emission products quantitatively determined.

The five ground level stations were operated for part of the 1967 and all of the 1968 fire seasons at Miller. Their specific locations are shown in figure 7 in the Results section.

Aircraft monitoring of smoke plumes from fires conducted during daylight hours was possible. For these, the aircraft flight tracks were of three types: (1) circling and penetration of the smoke column rising above the fire, (2) circling outside the column to observe and measure the rate of plume rise during the early phases of burning, and (3) intercepts of the altitude-stabilized smoke plume as it drifted downwind from the fire. The plumes were tracked and concentrations of carbon dioxide (CO_2) and particulates were monitored with onboard instrumentation—a CO_2 gas analyzer and a nephelometer. The latter measures light scattering from particulates, which, in turn, is proportional to particulate concentration (Charlson 1968).

The height of smoke columns from 22 fires at Miller was measured. These heights were, among other things, correlated with atmospheric mixing depth, obtained through standard radiosonde ascents made locally immediately before each fire.

Instrumented "burning tables" in laboratories at the University of California (Riverside) and Washington State University (Pullman) were used to burn samples of several pounds and 3.5 oz (100 g), respectively, and to analyze the particulate, carbon monoxide, and carbon dioxide emission rates. The data from these analyses, though useful, had to be used with caution because fire characteristics and intensity on a burning table are far different than those observed in the field.

The silvicultural research required measures of soil water content, soil temperature, root mortality, duff reduction, seedbed condition, conifer seed production and dispersal, seedling establishment, natural regeneration, and survival and vigor of planted trees.

Water content of the surface 4 inches (10 cm) of mineral soil was measured gravimetrically before and after burning. These were supplemental to the duff water contents taken by the fire scientists. The temperatures reached during burning were approximated to a 6-inch (15-cm) depth into the soil at 36 points on each unit with the use of asbestos strips treated with temperature fusible paints (Shearer 1975). Also, duration of soil temperature maximums was recorded at a few selected points with thermocouples buried at four depths, down to 1.6 inches (4 cm). Root mortality of nonconiferous vegetation was sampled at six points within each unit using a chemical test developed by Hare (1965). Relationships among root mortality, soil water content, and soil heating were tested and reported by Shearer (1975).

Seedbed condition was categorized on subplots in each treated unit after burning. Seed crops of the primary tree species were estimated. Production and dispersal of conifer seed at Newman were sampled from 1969 through 1974 and related to climatic and other variables.

Germination of conifer seed sown on typical postfire seedbeds was tested for several years on both blocks. Season, weather, and, particularly, duff depth were correlated with germination and survival. In addition, natural regeneration was tallied on plots at both Miller and Newman.

Though the results are not reported in this publication, 13 units at Miller and 7 units at Newman were planted with selected conifer species over a span of several years. Survival and vigor of this planted stock are being monitored.

Recovery and development of vegetation after the clearcutting and burning treatment were monitored on 20 units, 14 of them at Miller, the remaining 6 at Newman. Two permanent 16- by 82-foot (5- by 25-m) transects per unit were inventoried before and after treatment and continue to be sampled through time. Nested plots within these transects were used to sample different vegetational components. Tree basal area was measured and density of trees and shrubs per unit area was counted. Frequency of occurrence of herb and low woody plant species was determined. Cover (areal crown area) and volume (crown area × height) were measured or estimated for all vegetation components. Also, the amount of exposed surface not covered by vascular plants was estimated in the categories of rock, moss, litter, or bare ground. The largest plots (16 by 16 ft) were used for trees. The smallest (1.6 by 1.6 ft or 0.5 by 0.5 m) were used for herbs, small shrubs, and ground surface estimates. Individual species occupying a sixth or more of the plot were tallied.

Small mammals were trapped in the autumn of each of several years to ascertain population size and species composition as affected by treatment. The methods differ between areas. Kill-traps were employed at Miller—permitting population trends to be evaluated between years and treatments. At Newman live trapping furnished estimates of population densities.

In each sampled unit at Miller, 60 Museum Special kill-traps were placed in two parallel lines, with 10 trap stations in each line. These were baited with a peanut butter and oatmeal mix and set for 3 days of each year. Trapping began prior to logging in 1967 and continued through 1976, with 5 to 11 units being sampled each year. Results are expressed as numbers caught per trapping effort, with the trapping effort at Miller being 180 trap-nights per unit per year.

Newman was sampled with Sherman live-traps on two units (N-3 and S-3) and in two areas of adjacent undisturbed forest for 8 years (1969-1976). On each site, a 4.6-acre (1.9-ha) grid of 81 traps was used for 5 days annually. New animals caught in the 5-day period were marked and released, and population densities computed (Stickel 1954). A sampling of 1,620 trap-nights annually gave relative populations for comparison to results from the kill-traps at Miller.

Many soil physical and chemical characteristics as well as other parameters important to watershed behavior were sampled for several years at both Miller and Newman. Batteries of runoff plots were installed on each block, two plots per cardinal aspect in the burned units and one plot per aspect in the nearby undisturbed forest. Overland flow and sediment were caught in tanks below the 12 plots at Miller from 1967 through 1971 and again in 1974, and below the 12 at Newman from 1969 through 1972, 1974, and 1975.

Soil bulk density and total pore space measurements were obtained from soil cores. Soil organic matter content, particle-size distribution, and water-stable aggregation were measured from bulk soil samples taken within each plot. Measurements of live plant cover and litter were obtained with a point analyzer on 200 points established on transects within each plot. Total overland flow and eroded material were measured each year following spring snowmelt runoff, after each major high-intensity summer rainstorm, and in fall before the onslaught of winter. Nutrient contents of this water and sediment were analyzed for 4 years from Miller and for 2 years from Newman.

In addition to the data taken from the runoff plots, bulk soil samples were dug from 10 selected points within the central plots on 35 Miller units. The chemical characteristics of this surface foot (30 cm) of soil were determined before burning, after burning, and for 2 years thereafter. The parameters measured were pH; total contents of nitrogen, phosphorus, potassium, sodium, calcium, and magnesium; available phosphorus; cation exchange capacity; and exchangeable and soluble potassium, sodium, calcium, and magnesium. Only sufficient sampling was done at Newman to chemically characterize the soils there, not to measure the effects of treatment. Chemically, the Newman soils were found to be similar to those at Miller.

Water repellency was tested on most soil samples gathered from both blocks, and was also examined in the field at Newman.

Application of Results

Site, stand, habitat, and treatment descriptions are given so informed judgment may be used in the application of these research results. The forest environment continuously changes through space. Many facets of this environment were studied here. The more facets being considered, the more obvious environmental variability becomes, and the more difficult becomes the complete transfer of research results to another site.

The quantities cited in the results of this research often will apply only to the studied site; but the general relationships pointed out should apply widely. The same principle holds for the presence of plant or animal species. Other species may occupy similar niches in environments geographically removed from western Montana and may respond to treatment very much like those at Miller and Newman. The results from some disciplines, such as air quality management, will apply more broadly than will the results from others, such as silviculture.

It is up to the manager to decide if the results from this work may be partially or wholly applied to the set of conditions with which he is working. After reading the description for Miller and Newman and mentally comparing it to the site and treatment of concern, the manager on the ground must answer the following: Are the results applicable here? What results may apply? To what extent? Can I extrapolate the numbers to my situation? Or, do only the general relationships apply? The following guidelines may help this hypothetical manager answer these questions.

The results are applicable to clearcut sites in western Montana and surrounding States and Provinces with similar geology, soils, forest types, and habitat types if similar loads of logging residue are broadcast burned. Extension beyond this limited area requires careful judgment.

The predictions for duff reduction and exposure of mineral soil by fires are broadly applicable if fuels (broadcast conifer slash), surface organic horizons on the mineral soil, weather, and fuel moisture contents are similar. These may occur from Alaska to Arizona, from eastern Washington to Siberia. Wide application is possible because essentially only physical principles are involved and the effects of treatment are immediate. Neither biotic diversity nor the later action of weather or biological processes complicate the prediction.

The same holds for smoke management. These principles apply worldwide. The cited values for carbon dioxide, particulates, and height of smoke columns ought to be applicable to broadcast burning of conifer logging debris on areas of corresponding size in mountainous or very hilly terrain anywhere that fuel and climatic conditions are like those at Miller and Newman.

The silvicultural findings are more restrictive; they cannot be so widely applied. Both physical and biological processes are involved, and treatment effects may not be apparent for many years. Many more actions and interactions take place among a multitude of variables over a longer time to produce a given set of results than is the case for fire baring mineral soil, or for smoke rise and dispersion. Therefore, accurate prediction of long term silvicultural effects is risky. Nevertheless, the general aspects of conifer seed dispersal into openings, germination and survival of seedlings of these species on similar seedbed conditions, and the factors causing seedling mortality should apply quite broadly to the larch/Douglas-fir forest type. To fit the results more finely requires consideration of habitat types as well.

Vegetative development through the years after clearcutting and broadcast burning follows a seral pattern of herb to shrub to tree stages in many forest types. The time elapsed to progress from one stage to the next and the species involved in each stage will depend upon soils and climatic factors as well as upon plant geography and ecology. A widely applicable principle is that plant succession will be set back most and species composition will be most altered with the most intense fires. The time each listed species remains important in the plant community will be site specific, and probably cannot be extrapolated beyond the listed habitat types in western Montana, northern Idaho, and southern British Columbia, and then will apply only in series of years with weather similar to that experienced in 1967-1976.

Virtually the same guidelines apply to separability of the small mammal data to other forest types. The quantified population changes, species by species, will apply only to the same habitat types treated in a manner similar to that on Miller and Newman. Almost universally applicable, however, is the principle that clearcutting and fire removes the forest and causes marked declines in forest-dwelling species. This occurs with a concomitant increase in small mammals that inhabit early stages of plant succession. All levels of application between these two extremes are possible, being dependent upon the conditions with which the land manager is working.

Soils and watershed results are also dependent upon a combination of physical and biological processes. Immediate effects are largely physical—soil bared by logging and fire is subjected to overland flow and erosion, soil water repellency may be induced, and some plant nutrients will be volatilized in the fire. Effects manifested in the long term are largely driven by biological processes, such as recovery of vegetal cover on the soil, nutrient transport from the ash into the mineral soil and its later uptake by vegetation, and changes in organic matter content. The amount of soil bared is related to factors associated with fire effectiveness and can be predicted over a wide area. The amount of runoff and erosion to be experienced from a given amount of bare soil, however, will depend upon additional variables, such as slope, soil porosity and texture, and rainfall amounts and intensities. Hence, predictions of runoff and erosion are less widely applicable. The cited fertility changes will apply to similarly treated western conifer forests growing on well-drained soils of medium to fine texture; but the magnitude of these changes will vary from site to site.

Fire and smoke column from an evening prescribed fire in broadcast larch/fir slash.

RESULTS

This section is presented in six units, each written by the principal investigator(s) most closely associated with the specific data being discussed. These results are integrated and interpreted in the Discussion section that follows. The six units here are:

Fire Behavior and Effects—by Rodney A. Norum
Air Quality and Smoke Management—by D. F. Adams and others.
Silviculture—by Raymond C. Shearer
Vegetative Recovery and Development—by Peter F. Stickney
Small Mammal Populations—by Curtis H. Halvorson
Soils and Watershed—by Norbert V. DeByle and Paul E. Packer

Fire Behavior and Effects

Rodney A. Norum

Pacific Northwest Forest and Range
Experiment Station
Institute of Northern Forestry
Fairbanks, Alaska

The burning of forest fuels can vary tremendously, leaving widely different conditions afterward. As succeeding parts of this section will reveal, certain postfire conditions are important to the achievement of selected land management objectives. Perhaps most influential of all fire effects is the modification of the organic covering of the forest floor. The amount of duff consumed as well as the amount remaining each have a profound influence on vegetative response. The physical and chemical status of the soil is affected, along with watershed performance, and even the animal community may respond to differing degrees of duff removal. Therefore, one of the key objectives of the fire study was to determine the amount of duff removed and the amount retained when slash fires are burned under various conditions of fuel moisture and duff moisture, and with different amounts of fuel present. In addition, because of hazardous fire conditions represented by slash fuels, the amount of fuel consumed by fire over a range of fuel and atmospheric conditions was also measured.

Although the results of this study were reported by Beaufait and others (1977), results from subsequent fire research, combined with these, and a reanalysis of the pooled data have led to additional useful information. Applicable results from both Miller-Newman and later research and analyses are summarized here.

FUEL CONSUMPTION

Beaufait and others (1977) had difficulties statistically describing fuel consumption based on preburn measurements because treatments were biased by fuel loading values. Later research has not entirely relieved the problem, but a practical rule of thumb is now offered.

Small (<4-inch or <10-cm) diameter fuels are of paramount importance. They contribute most to the rate of spread on the fire front and to peak intensity. Consequently, they are most important to managers seeking fire hazard reduction. As discussed later, these fuels influence many important results of prescribed fires, such as duff reduction. Therefore an estimate of how much small fuel may be consumed in fires burning under selected and monitored conditions is necessary.

Experience on approximately 100 broadcast fires in larch/Douglas-fir forests, both on clearcuts and under standing timber, indicates that a safe and practical range of water contents is between 10 percent and 17 percent in the small diameter fuels. Below 10 percent water content the fire behavior and fire intensity becomes increasingly extreme, and control problems mount. Above 17 percent the fire becomes increasingly difficult to ignite and an effective fire treatment less likely. By pooling the data from Miller and Newman with subsequent data from fires burned within the 10 to 17 percent range, a simple but reliable estimate of reduction of fuels less than 4 inches (10 cm) diameter is possible with the linear regression equation:

$Y = 0.78X$

in which

Y = estimated reduction of small diameter fuels (kg/m^2)

X = preburn weight of small fuels (kg/m^2).

With the pooled data, this regression had a coefficient of determination (R^2) of 0.72.

For management, an obvious prescription criterion would be a water content between 10 percent and 17 percent in the small fuels. If burned within this range, approximately 78 percent of these fuels will be consumed. This is a safe and practical range of burning conditions that occurs frequently during late spring and early summer and again in late summer and early fall in the Northern Rocky Mountains.

Consumption of larger fuels (>4 inches or >10 cm in diameter) will vary from meager to nearly complete, depending on long-term drying conditions preceding the fire. Because of limited research results, no quantitative guidance for these fuels can be offered at this time.

DUFF CONSUMPTION

Duff depths and duff reduction measurements were taken on all fires as described by Beaufait and others (1977). They used upper duff moisture content and buildup index as independent variables in a regression equation to describe and predict duff depth reduction. Regression equations of duff weight on duff depth were derived in order to use the simpler depth measurements taken for fuel inventory purposes.

Subsequent to that report, the data from the Miller-Newman study were combined with identical data from 31 additional experimental fires in western larch/Douglas-fir forests and analyzed by a surface matching procedure developed by Jensen (1973). The results have been reported by Norum (1977) and are summarized here.

Table 2.—Percentage of duff depth consumed predicted from duff water content and fuel consumption

Water content of lower half of duff layer	Tons per acre (t/ha) of small (<4-inch or <10-cm diameter) fuels consumed			
	5(11)	10(22)	15(34)	20(45)
Percent	*------Percentage of duff depth reduction------*			
5	60	78	90	100
10	59	78	90	100
15	57	78	90	100
20	55	77	90	100
25	53	77	90	100
30	51	76	90	100
35	48	74	89	100
40	46	73	89	100
45	43	70	89	100
50	41	68	88	100
55	39	65	87	100
60	36	61	85	100
65	34	58	83	99
70	32	54	80	99
75	30	49	77	98
80	28	45	73	97
85	26	41	69	96
90	24	36	64	95
95	22	32	59	94
100	21	29	53	92
105	19	25	47	89
110	18	22	41	86
115	17	19	36	82
120	15	17	31	78
125	14	15	27	73
130	13	14	23	68
135	12	13	21	62
140	11	12	19	56
145	11	11	17	50
150	10	11	16	44
155	9	11	16	38
160	9	10	16	34
165	8	10	15	30
170	8	10	15	27
175	7	10	15	24
180	7	10	15	23
185	6	10	15	22
190	6	10	15	21
195	6	10	15	21
200	6	10	15	21
205	5	10	15	21
210	5	10	15	21
215	5	10	15	21
220	5	10	15	21

The percentage of duff depth removed is estimated in table 2. If the fire is conducted when the water content of small fuels is between 10 and 17 percent, the consumption of these fuels can be estimated as previously described. A measure of water content in the lower one-half of the duff layer completes the information necessary to use the table. The tabular value, combined with a set of duff depth measurements from the proposed fire area, offers a means to estimate the percent of the area that will be burned bare to mineral soil. This procedure and an example are presented in appendix B. The procedure works because duff reduction has remarkably little variation on any given broadcast burned area in this forest type if the fuels are uniformly distributed. For example, only three of the Miller fires had standard deviations in duff reduction greater than 1.2 inches (3 cm); 70 percent of the fires had standard deviations less than 0.8 inch (2 cm). This is a considerable asset to managers who desire to remove a specific amount of duff or to bare a prescribed amount of mineral soil for conifer regeneration. The depth of duff varies considerably over any selected site in these timber types, so the removal of a uniform layer of duff allows the exposure of some mineral soil, yet leaves other locations on the burned area protected by a covering of duff.

IGNITION PATTERNS

Significantly, neither the amount of fuel consumed nor duff removed was influenced by ignition patterns or techniques. The fires at Miller and Newman were ignited by center-firing, by flank-firing, and by combinations of these. In subsequent experimental fires, strip head-firing was added. No difference in duff reduction or fuel consumption could be related to pattern of ignition. The estimation procedures reported here are equally effective for any of the ignition techniques. This is of considerable importance to fire managers who must frequently design and adjust ignition patterns to assure fire coverage and yet maintain control.

Attempts were made to describe fire behavior through rate of spread measurements. We intended to ignite the fires in a pattern that burned the central 2.5 acres (1 ha) of each unit with a forward-spreading fire front. This was rarely achieved. The various ignition patterns caused a variety of fire front configurations in and through the plots. See cover photo for one example. Although the spread rate was measured on some fires, not enough data were collected for analysis, and therefore no conclusions are drawn.

Airborne monitoring of the smoke plume from prescribed fire on units S-4 and S-10 at Miller. (Washington State University photo)

Air Quality and Smoke Management

D. F. Adams, E. Robinson, P. C. Malte, R. K. Koppe, and N. V. DeByle

All except DeByle with Washington State University, Pullman

Fires in the forest, whether controlled slash fires of limited area or wildfires of more extensive coverage, generate large amounts of highly visible smoke that drift many miles downwind. The rapid oxidation by fire of many tons of fuel produces particulate matter and gaseous emissions, the composition of which varies depending on the efficiency of combustion and the nature of fuels. The composition, movement, and dispersal of smoke from many selected fires at both Miller and Newman were measured.

GROUND LEVEL PARTICULATES

Particulate matter concentrations in the atmosphere range from a low of 10 $\mu g/m^3$ of air in rural areas to 200 $\mu g/m^3$ in many urban locations; very dusty air may contain 2 000 $\mu g/m^3$. In Montana, a Glacier Park background site averaged 52 $\mu g/m^3$ and a Helena urban site averaged 89 $\mu g/m^3$ for the same time period. A concentration of 30 $\mu g/m^3$ limits visibility to about 25 miles (40 km) whereas 200 $\mu g/m^3$ reduces visibility to 3.5 miles (5.6 km) (Beaufait 1971; U.S. Department of Health, Education, and Welfare 1969).

Figure 7 shows the distribution of the five particulate monitoring stations near the Miller block. Monthly average values from them for 1968 are shown in figure 8. Site 5, in the urban and rural valley between Columbia Falls and Kalispell, had the highest mean monthly values of all stations for 7 of the 8 months that it was in operation.

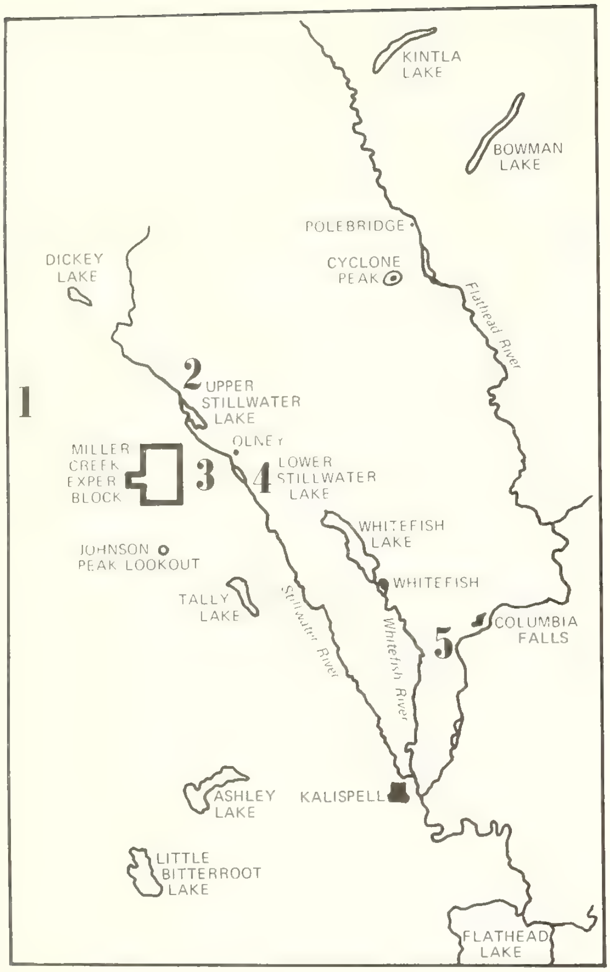

Figure 7.—Location of the five air quality stations at ground level in the vicinity of the Miller study area.

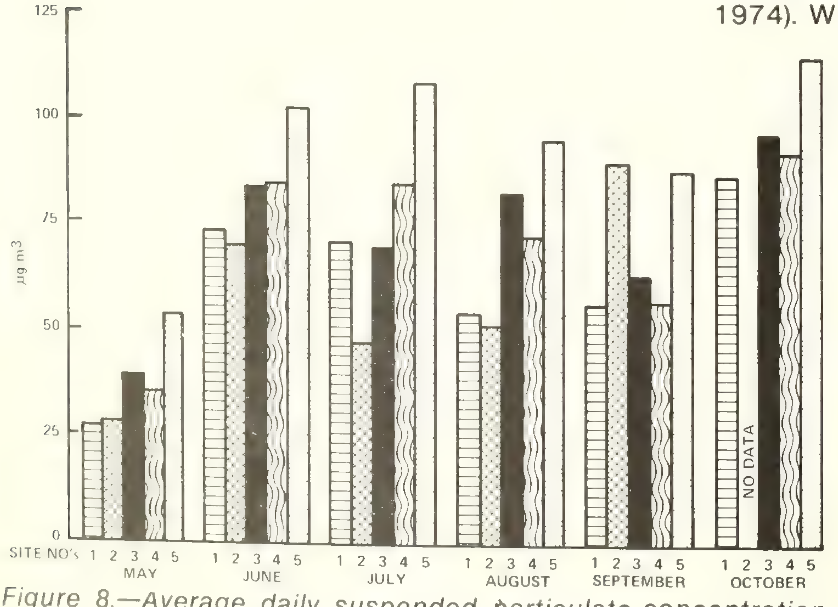

Figure 8.—Average daily suspended particulate concentration by months in 1968 at five air quality stations near Miller.

These data were analyzed by (a) all days with prescribed fires, (b) all weekdays with no fires, (c) all weekends, and (d) all days. Sites 3 and 4 have highly significant differences between fire days and all other day types (fig. 9); they are downwind from the prescribed fires. Sites 1 and 2, located west and north of the Miller block, did not have statistically significant differences by types of days. Site 5 also showed statistically significant differences between fire days and other weekdays. This site also had highly significant differences between nonfire weekdays and weekends, reflecting the influence of weekday commercial and industrial activities (such as tepee burners) in this valley. An analysis was run comparing the day after fires to all other nonfire days. They were statistically alike, indicating no holdover of particulate matter in the air from the previous day's fire.

Interestingly, there were higher average values on weekends at the four forest sites than on nonfire weekdays, probably due to dust from increased recreational traffic on forest roads and trails on weekends.

AIRCRAFT MONITORING OF SMOKE AND EMISSIONS

The height attained by the smoke columns from 22 of the Miller fires was measured. A regression analysis showed that relative fire intensity, water content of the upper half of the duff layer, windspeed at 20 feet (6.1 m) above ground (local surface windspeed), and atmospheric mixing depth at time of burning explained 80 percent of the variability in smoke column heights (Norum 1974). Within the range of atmospheric stability

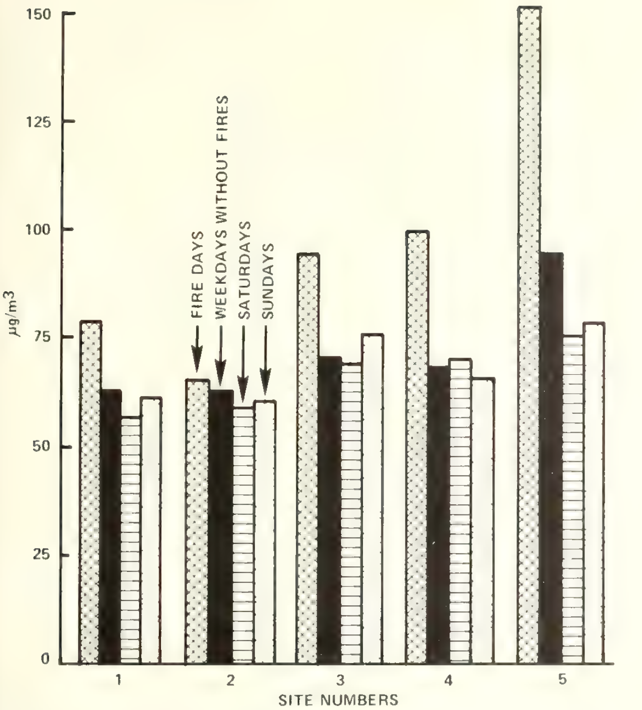

Figure 9.—Mean concentration of suspended particulates for fire days, other weekdays, and weekends from June to October 1968 at the five stations near Miller.

conditions under which these fires were conducted, those variables most closely associated with fire intensity (wind and fuel dryness) and a measure of fire intensity itself (evaporation from water can analogs [Beaufait 1966a]) were more influential than mixing depth in controlling the height of smoke rise. Norum (1974) concluded that atmospheric stability alone is inadequate for describing level of smoke rise from high-intensity 10-acre (4-ha) broadcast slash fires.

The smoke plumes were tracked with the airborne nephelometer more than 30 miles (approximately 50 km) downwind from several fires. Particulate matter in the downwind plumes from the Miller fires ranged from 90 to 230 $\mu g/m^3$; average background loading at that elevation was 18 $\mu g/m^3$. At the same time, carbon dioxide (CO_2) levels approximately 10 percent above background levels were found in the plumes nearly 16 miles (25 km) from their source. As the plumes grew and developed, there was a simultaneous increase in CO_2 concentration and particulate matter concentration that could be detected up to several miles downwind. The fact that CO_2 peaks coincide with visible plume and particulate peaks indicates that a large portion of the solid particulate matter is in a size class that moves essentially as a gas.

Energy from the relatively intense fires monitored by the aircraft pushed smoke plumes well above the mixing depth. Plumes from some intense fires at Miller rose up to 8,000 feet (2 440 m) higher than the mixing depth. As a result, even when the combustion products drifted south and over the populated valley, the plume was at least 3,300 feet (1 000 m) above the polluted valley air, and the plume could readily be tracked further downwind without confusion. On the other hand, less intense fires produced smoke columns that rose only to the mixing depth. Such fires may pollute the valley air, especially if they smolder into and through the night. This type of fire may have contributed to increased particulate matter levels at Station 5 on fire days. Of course, fallout of larger particulates downwind from intense fires would account for much of the increases at Stations 3, 4, and 5 on fire days, too.

Smoke plumes from the combined burning of units S-4 and S-10, and from the separate burning of E-10 and E-14 on Miller were closely monitored. The combined S-4 and S-10 plume rose to 14,400 feet (4 400 m) at a rate of 5 ft/s (1.5 m/s). Approximately 455 tons (413 t) of fuel were consumed. The columns from E-10 and E-14 rose to 11,500 feet m.s.l. elevation (3 500 m) at rates of 4.3 and 6.6 ft/s (1.3 and 2.0 m/s), respectively. The fuel consumed, exclusive of the duff, was approximately 132 and 176 tons (120 and 160 t), respectively. The greater energy release from the larger quantity of fuel on E-14 may have caused the greater rate of column rise, as both of these were burned the same evening under similar atmospheric conditions. Also, both ambient air temperature and height of free air convection were greater during the S-4 and S-10 fires, additional causes for the column from this fire to rise almost 4,000 feet (1 200 m) higher than the columns from the fires on E-10 and E-14.

The prescribed slash fires produced rapidly changing conditions for generation and rise of combustion products. Usually there was a rapid rise in the rate of energy release that resulted in rapid plume development and a boost of that plume to relatively high elevations. Then, after burning intensely, as illustrated on the cover photo, for, say, an hour, the available fuels were consumed and the fire quickly died down. The convection column rose from 4 to 7 ft/s (1.3-2.0 m/s) during this rapid rise in energy release rates. After reaching their ultimate height, the smoke plumes tended to concentrate at the level of greatest windspeed. There they moved with the wind as gradually widening rivers of smoke of limited depth. Aircraft monitoring of lateral smoke dispersion showed that the expected dispersion from a point source, a smoke stack, applies equally as well to dispersion of these smoke plumes (Adams and others 1976). The particulates in this smoke, for the most part, remain aloft as aerosols embedded in the air layer into which they were initially lifted. Most of these particulates ultimately would become condensation nuclei in precipitation and return to the earth's surface.

A number of nephelometer readings were used to construct a composite vertical profile of visibility on July 11, 1969, during a time when smoke was being transported into western Montana from fires hundreds of miles away. Visibility was restricted to approximately 5.6 miles (9 km) between 8,000 and 12,000 feet (2 440-3 660 m) elevation above m.s.l. but increased to approximately 9.3 miles (15 km) in the layers both above and below. This illustrates the point that smoke is advected into stratified layers in the atmosphere and remains there while moving along with wind currents.

Measurements of local winds aloft are essential to develop a reliable forecast, especially for plume behavior and dispersal. This need is pointed out with the data from aircraft monitoring of plumes from Miller fires S-4 and S-10 on July 3, 1968 (fig. 10). Speed of plume travel and the difference between ground and airspeed of the plane indicated an average wind of 40 mi/h (18 m/s) between 7,100 feet and 12,950 feet m.s.l. (2160-3950 m) at the study area. In contrast, RAWINSONDE measurements at the nearest station having this capability (Spokane, Wash., some 242 miles [390 km] away) showed windspeeds of only 13 mi/h (6 m/s) at that altitude. The direction at Spokane correlated well with the measured trajectory of the smoke column, but the windspeed was only 35 percent of that over the study area.

Peak concentrations of particulate matter near 1650 μg/m^3 were observed in the smoke plumes from the Newman fires in 1969. This may be an upper limit to smoke concentrations in an atmosphere with neutral temperature lapse conditions at distances up to 6 miles (10 km) downwind from the source. Concentrations of this magnitude are considered hazardous to health (U.S. Department of Health, Education, and Welfare 1969), reduce visibility to approximately one-half mile (800 m), and are an aircraft navigation hazard.

Several monitored plumes had a forked pattern similar to the plume from Miller S-4 and S-10 shown in figure 10. It is speculated that the combined forces of directional shear in the vertical and irregular energy release rates by the fire both contributed to this pattern.

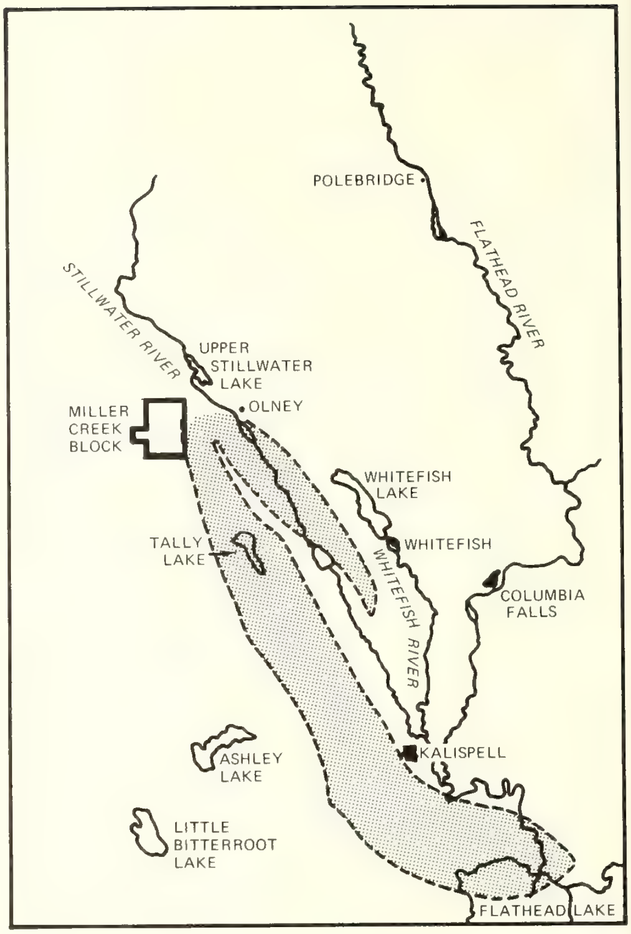

Figure 10.—Map of the maximum monitored spread and configuration of the smoke plume at 13,000 feet above MSL from the slash fire on units S-4 and S-10 at Miller on July 3, 1968.

SMOKE COMPOSITION

The largest components of forest fire smoke are carbon dioxide, water, and particulate matter. As already noted, particulates and carbon dioxide were detected above background levels in the plumes from the prescribed fires at Miller and Newman. The particulates may be organic or inorganic and are usually composed of carbon or mineral ash. The amounts of particulate matter and some gaseous emissions from inefficient fires are greater than those from efficient fires. The differences are roughly proportional to combustion rates. A fire that burns intensely may produce only a tenth as much particulate matter and unburned byproducts as one that burns slowly, spanning day and night and over a range of burning conditions (Beaufait 1971).

The fuel weights before and after burning the experimental units were sampled in detail. On the average, 60 percent of the fuels were consumed.

These fuel inventories, chemical analyses of the fuels, and analyses of combustion products from burning small quantities of these fuels in the laboratory were used in conjunction with the limited analyses of components in a few prescribed fire plumes to estimate the emission products from these fires.

Malte (1975) examined the results from three Newman fires (N-1, S-2, and W-2) in detail. He calculated ratios of particulate density to CO_2 density, usually finding a correlation (figs. 11 and 12). The particulates and CO_2 moved more or less together in the plume. Fire S-2 (fig. 11) clearly showed an increase in particulate matter (visible smoke) relative to CO_2 with time, whereas fire W-2 (fig. 12), burning more rapidly, had a peak ratio about 60 minutes after ignition.

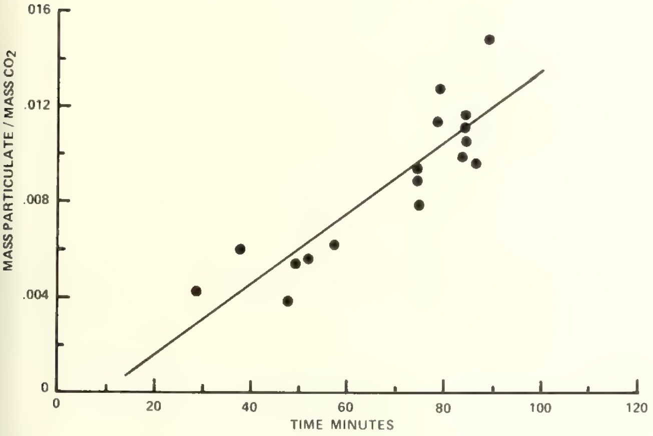

Figure 11.—Ratio of particulate concentration to carbon dioxide concentration in smoke plume from unit S-2 at Newman.

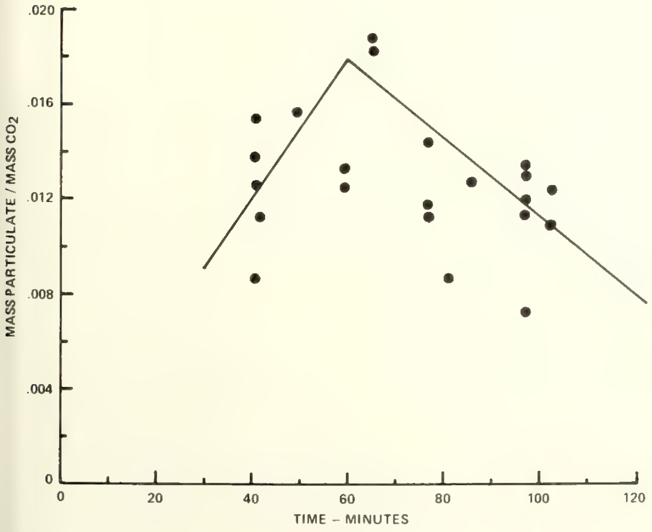

Figure 12.—Ratio of particulate concentration to carbon dioxide concentration in smoke plume from unit W-2 at Newman.

Figures 13 and 14 illustrate the concentrations of particulate matter and carbon dioxide, respectively, in the plume from fire S-2. Straight lines are drawn through data obtained at similar downwind positions, for example, at relative position "2". Of the three fires, this one best shows the increase in both CO_2 and particulate matter in the plume as the fire developed and grew. Concentrations in fire S-2 were only about half as great as in W-2 and the rates of increase were much lower, indicating that fire W-2 was the more intense of the two and burned at a faster rate. For fire N-1 the trend of increasing particulates with increasing time is similar to that observed in S-2 and W-2, with the values being about the same as for S-2. However, such weak CO_2 signatures were obtained from N-1 that its concentration in the plume could not be distinguished from background.

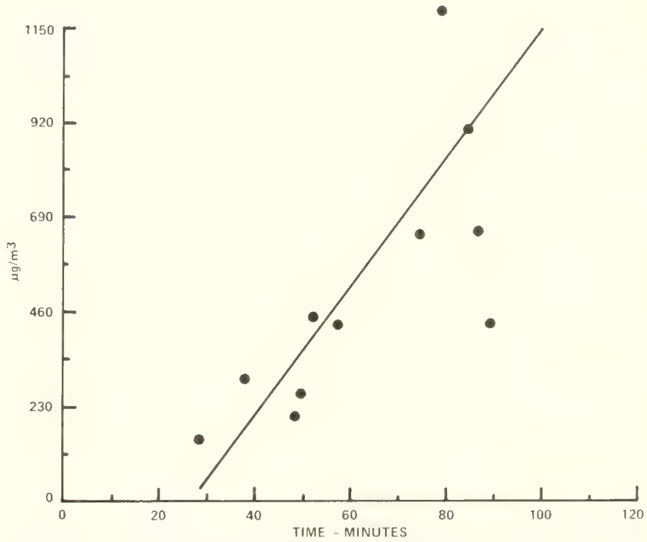

Figure 13.—Particulate concentration over time in the smoke plume from unit S-2 at Newman.

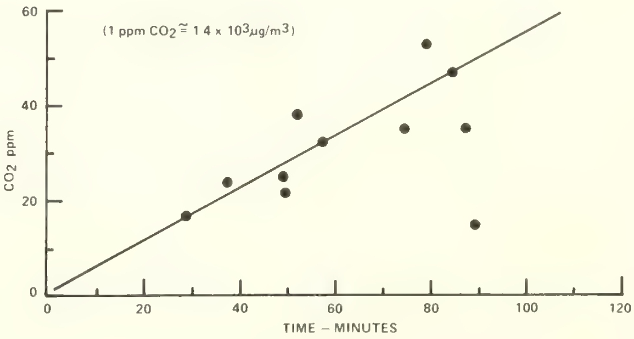

Figure 14.—Carbon dioxide concentration in the smoke plume from unit S-2 at Newman.

Generally, the ratio of particulate matter to CO_2 will vary with time and with position in the plume due to phenomena that are fluid dynamic or chemical in nature. As the fire grows, the intensity of convective currents increases, and particulates will be carried more readily by the plume gases. As downwind location is increased, less particulate matter is expected because of relatively rapid upwind fallout of the coarse particulates, those that are larger than aerosols. The nature and efficiency of combustion processes affect the formation of smoke and, thus, the ratio of particulate to CO_2. As the different slash fuel sizes and types undergo drying, pyrolysis, gasification, and surface oxidation, the nature of the overall fire and its smoke production change. In these fires it was found that an increase in the water content of fuels led to a reduction in the amount of carbon dioxide produced per unit of burned slash.

Chemical analyses of the fuels by category (duff, needles and twigs, and material larger than 4 inches [10 cm] in diameter) and of their combustion products were carried out in the laboratory. Duff and its residue after burning, for example, were found to contain the following elements in percentage of total ovendry weight:

	Duff	**Burned residue**
	Percent	
Carbon	37.3	8.6
Hydrogen	3.3	0.4
Nitrogen	1.5	0.4
Oxygen	15.4	0.9

Burning increased the ash content to 89.7 percent. This duff, burned when dry, gave a CO_2 ratio of 0.885; the remainder (0.115) was assumed to be carbon monoxide (CO).

Without going into the details of the stoichiometric procedures followed, as they are covered by Malte (1975), the following formulas were developed to calculate the total amounts of carbon dioxide (formula 1), carbon monoxide (formula 2), and nitrogen dioxide (formula 3) produced from the different fuels in a slash fire:

$$\begin{aligned} \text{kg } CO_2 = {} & 2.08\, Y_M \left(\frac{W_i}{1+M} - W_f\right)_{\text{duff}} \\ & + 1.66\, Y_M \left(\frac{W_i}{1+M} - W_f\right)_{\text{needles and twigs}} \\ & + 1.76\, Y_M \left(\frac{W_i}{1+M} - W_f\right)_{\text{branches and logs}} \end{aligned} \qquad (1)$$

$$\begin{aligned} \text{kg CO} = {} & 4.63\, (1.038\, Y_M) \left(\frac{W_i}{1+M} - W_f\right)_{\text{duff}} \\ & + 1.05\, (1.038\, Y_M) \left(\frac{W_i}{1+M} - W_f\right)_{\text{needles and twigs}} \\ & + 1.13\, (1.038\, Y_M) \left(\frac{W_i}{1+M} - W_f\right)_{\text{branches and logs}} \end{aligned} \qquad (2)$$

$$\begin{aligned} \text{kg } NO_2 = {} & 0.08 \left(\frac{W_i}{1+M} - W_f\right)_{\text{duff}} \\ & + 0.034 \left(\frac{W_i}{1+M} - W_f\right)_{\text{needles}} \end{aligned} \qquad (3)$$

In these formulas the terms are defined as:

Y_M = moles CO_2/moles total carbon as determined from the relationship with water content of fuel. Ratio is 1.000 with no water, decreases 0.022 with each 10 percent increase in water content, and, thus, is 0.890 at 50 percent fuel water content.

W_i, W_f = initial and final (residue) masses of individual slash fuels, including moisture content of initial fuel.

M = water content as decimal fraction for individual slash fuels.

Potentially, most of the NO_2 would have come from the burned duff (it contained 1.5 percent N) and needles (they contained about 1.0 percent N) in the total fuel bed because the woody twigs and larger fuel components had less than 0.05 percent N content. Hence, formula 3 includes only duff and needle categories.

The emission of CO_2, particulate matter, CO, and NO_2 per unit of consumed fuel are presented and discussed for the Newman fires. To do this, formulas 1, 2, and 3 were used together with fuel water contents and pre-and postburn inventories for these units. The water contents for the different fuel components on these units are presented in table 3. The ranking of fires from wet to dry is: S-2, average of all eight Newman fires, N-1, and W-2.

Table 3.—Water content of Newman fuels

Unit	Duff[1]	Needles[2]	Diameters of woody fuels		
			[2]0-1 cm	[2]1-10 cm	[3]10+ cm
	Percentage of ovendry weight				
N-1	35.5	6.2	10.0	11.1	12.2
S-2	53.2	5.4	8.1	22.0	35.9
W-2	29.8	5.5	8.6	11.1	13.6
Average of 8 units	37.5	8.2	10.2	13.7	17.2

[1] Average of upper and lower duff.

[2] Average of upper one-fourth and lower one-fourth of fuel bed.

[3] Extrapolation, assuming same difference between moisture content for 10+ cm material and 1-10 cm twigs as between moisture content for 1-10 cm twigs and 0-1 cm twigs.

Table 4.—Fuel inventory of selected Newman units

Unit and conditions	Duff	Needles	Branches and stems			Total
			0-1 cm	1-10 cm	>10 cm	
N-1	*kg/m^2*					
Before	109.8	4.00	2.92	19.2	247.8	383.7
After	53.1	.03	.02	2.9	139.4	195.4
Burned	56.7	3.97	2.90	16.3	108.4	188.3
Percent burned	*52*	*99*	*99*	*85*	*44*	*49*
S-2						
Before	106.0	2.54	2.54	25.9	213.8	350.8
After	56.5	.58	.58	4.2	57.0	118.8
Burned	49.5	1.96	1.96	21.7	156.8	232.0
Percent burned	*47*	*77*	*77*	*84*	*74*	*66*
W-2						
Before	106.6	2.48	2.07	23.4	237.0	371.6
After	60.7	.04	.03	2.1	86.0	148.9
Burned	45.9	2.44	2.04	21.3	151.0	222.7
Percent burned	*43*	*98*	*99*	*91*	*64*	*60*
Average of 8 units						
Before	110.9	3.5	2.56	27.1	209.5	353.6
After	63.4	0	.20	3.3	93.5	160.4
Burned	47.5	3.5	2.36	23.8	116.0	193.2
Percent burned	*42*	*100*	*92*	*88*	*55*	*55*

Fuel inventories for these Newman units are presented in table 4. Slightly over half of the total fuel consumed was larger than 4 inches (10 cm) in diameter. Duff represented about a fourth of the burned fuel, twigs one-third to 4 inches (1-10 cm) diameter comprised a tenth, and small twigs and needles contributed equally to the remainder.

Table 5, the mass of gases and particulates produced per mass of total fuel burned, is derived from the above formulas and tables 3 and 4. The particulate emission index was determined by multiplying the CO_2 emission index by the mass ratio of particulate matter to CO_2, which was determined from aircraft measurements of the smoke plume. A value is given only for W-2 since this was the single case for which plume data were sufficient to estimate the particulate/CO_2 ratio. A value for NO_2 is given only for the average of the eight Newman fires. At most, only 1 percent of the total slash fuel could form NO_2.

Generally, needles and small twigs gave negligible (<3 percent) contributions, except for NO_2, because of the small quantities present. The duff and larger twigs and branches (1-10 cm) each contributed slightly more than 10 percent of the CO_2; but the primary contribution to CO_2 was material larger than 10 cm in diameter. For CO the situation was somewhat different—duff and material >10 cm were the major CO sources, each contributing about equal amounts.

The mass of CO emitted per mass of burned fuel was essentially constant in all fires, having a value about 0.13. However, the mass of CO_2 emitted increased with decreasing water contents of the fuel. The ranking of the fires from low to high CO_2 formation is identical to the ranking of fuels from wet to dry. Note also that the concentrations of CO_2 in the plumes of fires S-2 and W-2 illustrate dependence on fuel water content; the CO_2 concentration in the plume from the dry fuels on W-2 was about twice as great as from the wetter fuels on S-2. Apparently the conversion of fuel carbon to CO_2, rather than CO, was enhanced by more efficient combustion of the dry fuels.

The amount of particulate matter produced per unit of fuel burned should be of concern to the manager. Calculations of this parameter, using different portions of these air quality data, gave results from approximately 10 lb of smoke particulate per ton of fuel burned (burning table date), to 33 lb per ton (using factor 0.016 in table 5), to 48 lb per ton (Miller smoke plume data). Though more reliable data would be desirable, a reasonable estimate from these data is approximately 30 lb of particulate matter produced in the smoke from each ton of fuel (15 kg/t) consumed in these fires.

Table 5.—Mass of CO_2, CO, particulates, and NO_2 per mass of total slash[1] burned on selected Newman units

Unit and component	Source of contribution					
	Duff	Needles	Branches and stems			Total
			0-1 cm	1-10 cm	>10 cm	
N-1						
CO_2	0.248	0.033	0.023	0.124	0.740	1.168
CO	.080	.001	.001	.005	.033	.120
S-1						
CO_2	.100	.013	.012	.116	.703	.944
CO	.038	.001	.001	.007	.093	.140
W-2						
CO_2	.235	.022	.017	.173	1.179	1.626
CO	.058	.001	.001	.007	.055	.122
Particulates	—	—	—	—	—	.016
Average of 8 units						
CO_2	.169	.027	.018	.170	.745	1.129
CO	.050	.001	.001	.013	.065	.130
NO_2	.007	.001	—	—	—	.008

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[1] Including water content of slash.

Western larch seedling developing in the protection of a charred log on Miller unit W-1 6 years after broadcast burning.

Silviculture

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The interaction of seedbed condition, seed availability, and environmental factors restricts conifer regeneration following prescribed fires. Any of these alone may limit regeneration to unacceptably low levels. For example, mineral soil may not be exposed, no seeds may mature, or animal populations, insolation, or drought may cause excessive seedling mortality.

The conditions following prescribed fires in clearcuts at Miller and Newman are described and related to conifer regeneration. These results are contrasted with nearby uncut areas burned by wildfire or slashed but unburned clearcuts.

SEEDBED CONDITION

Prescribed fires from May through October on all cardinal exposures produced a wide range of seedbed conditions. Duff reduction was limited by duff water content. When the lower half of the duff was below 50 percent ovendry weight, almost all duff was burned. However, when the water content of the lower half of the duff was above 100 percent, usually less than half burned. Reduction in duff thickness ranged from 11 to 100 percent at Miller and from 65 to 90 percent at Newman.

Prescribed fires in logging slash caused only minor changes in soil water content and soil heating except during fires of high intensity, when the initial water content of both soil and duff was low. When the water content of soil and duff was high, fires caused no change in content of soil water and only a slight change in duff water. As duff dried, the prescribed fires burned a greater proportion of the duff layer, which, in turn, caused more water loss from and heating of the surface soil. When both fuels and upper soil had low moisture contents, water loss and heating occurred as deep as 4 inches (10 cm) into the soil. Soil heating associated with prescribed fires decreased rapidly below the soil surface (table 6). Maximum temperatures within the upper 1.6 inches (4 cm) usually were reached between 1 and 2 hours after ignition.

Table 6.—Maximum temperatures reached within the soil under three percentages of duff reduction[1]

Depth in soil	Percent duff reduction		
	23	61	82
Inches (cm)		*F(C)*	
0	142 (61)	234 (112)	320 (160)
0.4 (1)	125 (52)	163 (73)	196 (91)
1.2 (3)	<113 (45)	120 (49)	124 (51)
2.0 (5)	<113 (45)	<113 (45)	<113 (45)

[1] Adapted from Shearer (1976), p. 488-489.

During prescribed fires, significantly greater duff reduction and heating of the mineral soil surface took place at Newman than at Miller. Three-fourths of the sample points reached maximum temperatures between 200°F (93°C) and 400°F (204°C) at Newman but, at Miller, three-fourths reached only 138°F (59°C) to 163°F (73°C). Greater surface soil heating occurred at Newman because of a shallower duff layer and lower water contents of both fuel and soil than at Miller. Average duff reduction varied at Newman from 44 percent at 113°F (45°C) maximum surface soil temperature to 99 percent at 500°F (260°C); at Miller from 36 percent at 125°F (52°C) to 70 percent at 400°F (204°C).

Heat-caused mortality of nonconiferous roots or rhizomes varied according to soil water content and depth and degree of soil heating. Spring fires of any intensity caused root mortality only in the upper 0.4 inch (1 cm) of soil. Low-intensity fires over dry soils caused considerable root mortality in the surface 2 inches (5 cm) but relatively little below that level. Only the combination of high-intensity fire over dry soils killed most roots in the upper 4 inches (10 cm).

SEED PRODUCTION AND DISPERSAL

Good seed crops occur infrequently. At both study sites from 1969 through 1974, the only good seed crop was produced in 1971. Poor crops were produced in 1970 and 1974, and failures occurred in 1969, 1972, and 1973. At Miller a fair crop was produced in 1967 and a poor one in 1968. Most natural regeneration reported for both areas originated from the good 1971 seed crop. The fair 1967 crop partially regenerated cutover Miller units burned that year. In addition, three units of uncut trees, most of which were killed by a wildfire in late August 1967, disseminated considerable seed from fire scorched cones.

In 1971 the residual timber produced an average of 51,000 and 34,000 sound seeds per acre (126000 and 84000 per hectare) at Miller and Newman, respectively. The number of seeds produced by each species varied widely, usually reflecting stand composition. Although variability is great from unit to unit, an average of 37,000 sound seeds per acre (91 400/ha) fell into the 10-acre (4-ha) clearcuts at Miller, and an average of 10,000 per acre (24700/ha) fell into the much larger clearcuts at Newman. This represents only 29 and 12 percent, respectively, of the seedfall in the surrounding forest. A higher percentage of seed fell in clearcuts at Miller becuase the openings were smaller than at Newman.

The distribution of sound seed at Newman decreased sharply from the timber edge to about 300 ft (90 m) into the clearcut openings, then continued at a low but uniform rate up to about 800 ft (244 m) from the timber (table 7). The average number of sound seed per acre declined from 42,900 in the belt 0-200 ft from the timber edge to 11,500 in the belt 600-800 ft from the timber (106 000/ha in 0-61 m belt to 28 400/ha in 183-244 m belt). Seedfall was greatest within south-facing clearcuts; this was followed in order by west-, east-, and north-facing clearcuts. During the prime seedfall hours of noon to 6:00 p.m., when air temperature is highest and relative humidity lowest, average wind velocities were much higher on south- than on north-facing slopes. Velocities ranged from 3.5 to 5 mi/h (5.6-8 km/h) greater on south- than north-facing slopes during the primary hours seed is dispersed.

Table 7.—Cumulative number of sound seed per acre (hectare) dispersed from 1969 through 1974 on eight clearcut units on Newman by distance from seed source

Species	Within timber	Distance from timber edge within clearcut			
		0-200 ft (0-61 m)	200-400 ft (61-122 m)	400-600 ft (122-183 m)	600-800 ft (183-244 m)
	Hundreds per acre (hectare)				
Douglas-fir	1,228 (3 033)	217 (536)	103 (254)	42 (105)	84 (208)
Western larch	532 (1 315)	75 (186)	37 (92)	20 (49)	8 (19)
Ponderosa pine	276 (681)	21 (53)	12 (29)	6 (14)	0 (0)
Grand fir	241 (596)	69 (170)	19 (48)	23 (56)	15 (38)
Lodgepole pine	22 (54)	11 (26)	3 (6)	0 (0)	0 (0)
Engelmann spruce	30 (75)	30 (74)	8 (19)	3 (7)	8 (19)
Other	11 (26)	6 (16)	3 (6)	6 (14)	0 (0)
Total	2,339 (5 780)	429 (1 060)	184 (455)	100 (247)	115 (284)

The percentage of sound seed in the good 1971 seed crop at Newman was about three times greater than the average of the other five poor or failure crops as shown:

Area	Western larch	Douglas-fir	Engelmann spruce
Miller (1971)	16	43	48
Newman (1971)	15	39	45
Newman (all other years)	4	11	18

GERMINATION

Plots were sown so germination and the effects of environmental factors on tree seedling survival could be effectively measured. Initial seed germination varied by species, from several days before snowmelt (western larch) to about 3 weeks after (Engelmann spruce). Douglas-fir, grand fir, ponderosa pine, and lodgepole pine seeds began germinating soon after snowmelt. Germination usually peaked the week following snowmelt, then declined steadily, and ended within a month, with the exception of spruce. Some spruce seed continued to germinate throughout the summer whenever the surface soil was moist.

More germination occurred on soil bared by fire or scarification than occurred on soil remaining with a residual duff layer more than 0.5 inch (1.3 cm) thick. Germination differences between bare and duff-covered seedbeds were greatest on south- and least on north-facing slopes. However, more germination occurred on north- and east-facing slopes than on south- or west-facing slopes.

SEEDLING SURVIVAL

Several factors strongly influenced initial seedling survival. Severe seedling losses were caused by bird and rodent predation, by fungi, and by drought.

In the spring of 1968, migrating juncos killed over 90 percent of the newly germinated seedlings at Miller by clipping the cotyledons and removing seedcoats. After the seedcoats were shed naturally, these losses immediately dropped to a low but constant rate for the remainder of the summer.

Fungi caused considerable mortality of new seedlings until the surface soil dried, usually in mid- to late-June. These losses were greater on surfaces with scorched duff than on those burned to bare mineral soil. Fungi were the primary cause of seedling mortality at Newman on all but south-facing slopes.

Drought in late summer of most years caused extensive seedling losses. It was the leading cause of seedling death on south-facing slopes, and the second most important on all other aspects. Most losses occurred in August, except in 1968, when rainfall saturated the surface soil during this period.

Frost heaving caused mortality of germinating seed and seedlings during their first autumn and spring. In early spring, germinating seeds and the surface layer of soil were lifted by and suspended on ice crystals. When the ice melted, the seeds and young seedlings dried. Year-old seedlings also were killed when frost heaved because the roots were broken or exposed.

Despite partial shading from microrelief, charred logs, and stumps, surface soil temperatures reached as high as 175°F (79°C) on unprotected east-, south-, and west-facing clearcuts from mid-June through early August. These high surface temperatures no longer occurred after vegetal cover developed and provided more continuous shade. Most seedling losses occurred in July. Seedlings growing on north-facing slopes, where the maximum recorded was 131°F (55°C), were nearly unaffected. Due to direct solar radiation, soil temperatures 20 inches (50 cm) below the surface on burned areas were 5° to 14°F (3°-8°C) higher than in the adjacent forest.

NATURAL REGENERATION

Natural regeneration on burned seedbeds was most successful on north-facing slopes and least successful on south-facing slopes. Even small changes in aspect affected survival. For example, on a Newman unit that included slopes facing 96°, 110°, and 141° azimuth, the number of seedlings per acre in 1973 on these exposures, respectively, were 1,401, 865, and 516, and the proportions of milacre plots stocked were 50, 45, and 32 percent.

In August 1967 at Miller a wildfire swept through several uncut stands on east-, south-, and west-facing slopes and killed most trees. However, many of those trees dispersed seed that autumn from their charred cones. Shade from the dead trees moderated site conditions enough to increase seedling survival, particularly on south-facing slopes (table 8). The shaded south-facing slope had 11 times more seedlings than adjacent clearcuts; the shaded east- and west-facing slopes had about three times more seedlings than bordering clearcuts.

In contrast to the burned areas, very little natural regeneration survived on unburned seedbeds. On north-facing unburned slopes at Miller there were only 200 seedlings per acre (494 per ha) and only 17 percent of the milacre plots were stocked. Unburned south-facing seedbeds had a mere 33 seedlings per acre (82 per ha), with a 3 percent stocking. Most seedlings growing under these conditions had poorer vigor and height growth than those growing on burned areas.

The number of filled seeds required to establish a seedling varied by habitat type and by the interaction of aspect and seedbed condition (table 9). At Newman the average seed/seedling ratio for all habitat types was inversely related to initial root elongation and to seed weight. That is, species with heavy seed and rapid initial rooting had low ratios while light seed and slow initial rooting had high ratios (table 10).

Table 8.—Seedlings per acre (hectare) and stocking of milacre plots under burned standing timber versus that on adjacent burned clearcuts at Miller in 1974

Aspect	Burned uncut forest		Clearcut and burned	
	Seedlings	Stocking	Seedlings	Stocking
	Number	*Percent*	*Number*	*Percent*
East	2,467 (6 096)	87	895 (2 212)	47
South	1,588 (3 924)	63	141 (348)	15
West	5,454 (13 477)	92	1,726 (4 265)	76

Table 9.—Average number of seeds required to establish one seedling at Miller and Newman by habitat type (Pfister and others 1977) and aspect—seedbed condition (Shearer 1976)

Habitat type	Aspect—seedbed condition	Seeds per seedling
Miller:		
Abies lasiocarpa/Clintonia (*Menziesia* phase)	Upper north and east—burned to mineral soil	17
Abies lasiocarpa/Clintonia (*Clintonia* phase)	Lower north, east, and west—burned to mineral soil	67
Newman:		
Thuja/Clintonia (*Menziesia* phase)	North—burned to mineral soil	6
Abies grandis/Clintonia	Northeast to east—burned to mineral soil	17
Abies grandis/Xerophyllum	East and southeast—burned to mineral soil	92
Abies grandis/Xerophyllum	West—burned to mineral soil	149
Pseudotsuga/Vaccinium globulare (*Xerophyllum* phase)	South—burned to mineral soil	185
Pseudotsuga/Vaccinium globulare (*Xerophyllum* phase)	South—rapid revegetation	659
Pseudotsuga/Vaccinium globulare (*Xerophyllum* phase)	West—scorched duff layer	668

Table 10.—Seed weights related to seeds required at Newman to establish one seedling

Species	Seeds per pound[1]	Seeds per seedling
Ponderosa pine	12,000	11
Grand fir	18,400	16
Douglas-fir	44,300	44
Western larch	137,000	53
Engelmann spruce	135,000	74

[1] From U.S. Dep. Agric., Agric. Handb. 450, 1974. Washington, D.C.

Vegetation development on a larch-fir forest site (Miller unit E-9) 5 years after clearcutting and broadcast burning represents a well developed herb stage in forest succession.

Newman unit S-3, in 6 years of successional development following clearcutting and broadcast burning, has passed through a 3-year herb stage to the shrub stage of forest succession.

Vegetative Recovery and Development

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During the first 6 to 9 years after burning, development of vegetation on the 20 units studied at Miller and Newman followed a pattern characteristic for forest succession in the Northern Rocky Mountains. This pattern is initiated by an herb stage, which is followed in turn by shrub and tree stages. In these few years, tree development was nonexistent or quite limited on most areas. Nowhere did trees attain community dominance. Using cover (crown area) of the predominant life form as the criterion for defining the successional stage, we find 9 of the 20 units had progressed to the shrub stage. All others remained in the herb stage.

HERB SUCCESSIONAL STAGE

The duration of the herb stage varied from 3 to 7 years on the 9 units that had progressed to the shrub stage. Seral vegetation that developed in the first postfire year originated from both surviving and newly established plants. This development varied widely in coverage, from less than 1 to 59 percent. Except for a few units, herbaceous plants comprised almost all of the cover in the first year. Values ranged from less than 1 to 57 percent, with half the units ranging from 5 to 27 percent herb cover. Herb cover increased rapidly for the first few years, particularly where fast-growing species such as fireweed *(Epilobium angustifolium)* were abundant members of the seral community. Herb cover usually reached maximum value by the second or third year, with coverages between 25 and 67 percent. Thereafter it leveled off or often declined 5 to 25 percent. This pattern of development for the herb component occurred whether or not there was a concurrent development of shrubs. On a few units this pattern was modified because fireweed and other rapidly developing species were absent. On these, the initial increase in cover was less rapid and peak development was delayed.

SHRUB SUCCESSIONAL STAGE

On most units, first-year cover values by shrubs were low, in the range of 0 to 3 percent. Early development of shrubs was slow but continuous while the community was in the herb stage and often dominated by fireweed. In this respect, shrub development contrasts markedly with herb development. Because most shrub growth is cumulative, its rate of increase grows with the passage of years. Thus, shrubs did not become the predominant component on units on which fireweed was the major herbaceous precursor until at least the sixth year of succession (fig. 15). Five units with this pattern reached the shrub stage in the sixth to eighth year, with coverages of 29 to 55 percent. This pattern of shrub development is characteristic of the Miller area, which contained four of the five units.

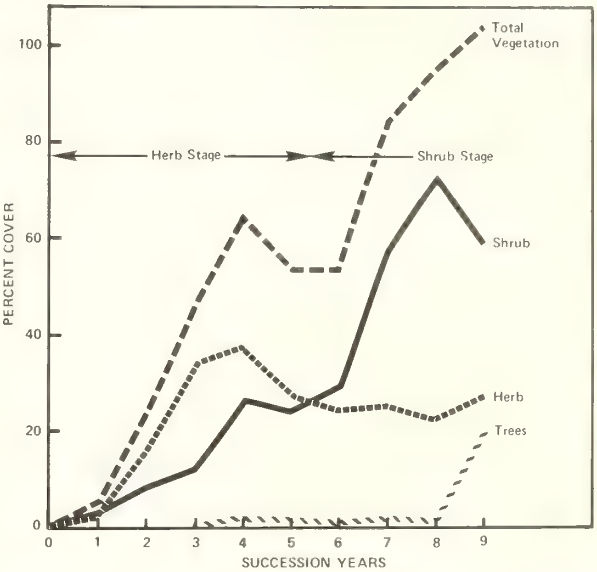

Figure 15.—Development of trees, herbs, shrubs, and total vegetative cover for 9 years following wildfire in standing timber (Miller S-13).

A variant of this pattern characterizes seral development of shrubs at Newman. Most units at Newman had higher coverages (7 to 17 percent) of shrubs in the first year. Development of the shrub component here closely paralleled that of the herb component for the first 3 or 4 years, then increased abruptly to become dominant in the fourth to fifth year, with coverages of 28 to 52 percent (fig. 16). Fireweed was absent or sparse on these sites.

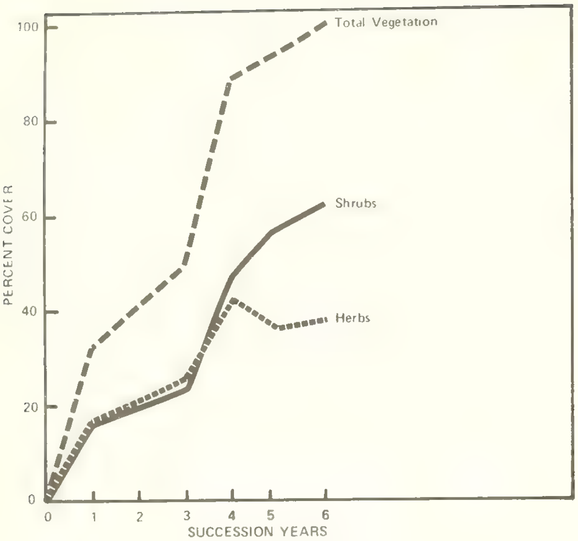

Figure 16.—Development of herbs, shrubs, and total vegetative cover for 6 years following an intense broadcast slash fire at Newman (S-3).

COMPOSITION OF LIFE FORM COMPONENTS

The herb and shrub components of the seral vegetation at Miller and Newman are characterized by 12 species. The forbs include: fireweed, broadleaf arnica *(Arnica latifolia)*, common beargrass *(Xerophyllum tenax)*, pinegrass *(Calamogrostis rubescens)*, northwestern sedge *(Carex concinnoides)*, autumn willowweed *(Epilobium paniculatum)*, and longtube twinflower *(Linnaea borealis)*. The shrubs include: snowbrush ceanothus *(Ceanothus velutinus)*, birchleaf spirea *(Spiraea betulifolia)*, blue huckleberry *(Vaccinium globulare)*, western thimbleberry *(Rubus parviflorus)*, and Scouler willow *(Salix scouleriana)*. All are native to this area. Some 42 percent of the total species are herbs or low woody plants. Rhizomatous species (fireweed, broadleaf arnica, pinegrass, and northwestern sedge) comprise more than half the herbs. Beargrass appears as a tussock plant but actually has a stout surface rhizome, willowweed is an annual, and twinflower is a mat-forming, low, woody plant. Three of the five shrub species (birchleaf spirea, blue huckleberry, and western thimbleberry) are rhizomatous low shrubs. The remaining two, snowbrush ceanothus and Scouler willow, are medium to tall root-crown shrubs.

Prefire resident species (five herbs: broadleaf arnica, common beargrass, pinegrass, northwestern sedge, and longtube twinflower; and three shrubs: birchleaf spirea, blue huckleberry, and western thimbleberry) comprised two-thirds of the postfire plant community. Of the remainder, three species invaded (fireweed, autumn willowweed, and Scouler willow), and one shrub (snowbrush ceanothus) was present as buried seed.

EFFECT OF FIRE

Despite similarity in appearance after fire, the effectiveness of burning (heat treatment) on the regenerative parts of plants showed a wide range over the 20 units studied. In general, the units at Newman received hotter treatments than those at Miller. This concept of burning treatment is a relative measure of the effectiveness of the heat imparted to a narrow zone both above and below the mineral soil surface. It is here that the surviving portions of most forest plants are located that permit their regeneration. A combination of lower duff water content and fire intensity (heat pulse to site) provides a rudimentary expression for the quantification of burning treatment. A highly effective (hot) burning treatment would result from a combination of dry duff (<50 percent water content) and a high fire intensity (>800 grams water loss from water can analogs [Beaufait and others 1977]). In contrast, a relatively ineffective (cool) burning treatment would result from a combination of wet lower duff (water content >100 percent) and low fire intensity (<500 grams water loss). The characteristic effects of a hot treatment are: (1) near to complete destruction of aerial portions of understory vegetation, (2) high mortality of surface and near-surface rhizomatous plants and fire susceptible root-crown plants, and (3) total to nearly complete reduction of the litter-duff layers.

A comparison of two south-facing units at Miller illustrates the effect of differing burning treatments on postfire vegetation in the *Xerophyllum* phase of the *Abies lasiocarpa/Clintonia* habitat type. The preburn forest was similar in structure and species composition, with an overstory composed of nearly equal proportions of Engelmann spruce, western larch, and Douglas-fir, and an understory of subalpine fir. Undergrowth in both was primarily huckleberry and beargrass. One unit was clearcut and broadcast burned; the other unit burned as standing timber by a wildfire. Burning treatment data for the clearcut and burned unit was: lower duff water content of 135 percent, and water can water loss of 286 grams (a cool burn); that for the wild unit was: lower duff water content of 56 percent, with no data for water loss, but fire intensity was great enough to completely consume the duff layer (a hot burn). All fine fuels in the slash and undergrowth vegetation on both units were consumed. On the broadcast-burned unit a charred but nearly continuously intact duff layer remained. This layer contained many "duff-cracks" from drying out after the fire. On the wildfire-burned unit all trees were killed and the ground surface was covered with ash and charred woody debris. No duff layer remained in evidence.

On the clearcut plot the herb stage reached its maximum cover (61 percent) by the third year and was still dominant after 9 years (fig. 17). Fireweed and beargrass constituted most of the herb cover (fig. 18). Huckleberry and two other resident shrubs, plus Scouler willow, an immigrant pioneer, made up the shrub component. All are slow developing shrubs.

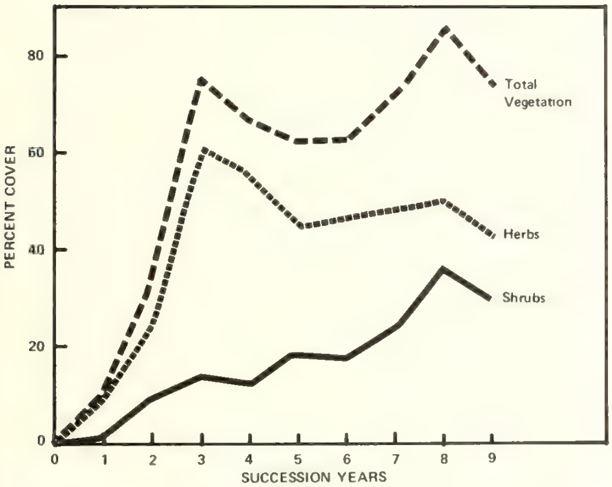

Figure 17.—Development of shrubs, herbs, and total vegetative cover over a 9-year period following a low-intensity slash fire at Miller (S-1).

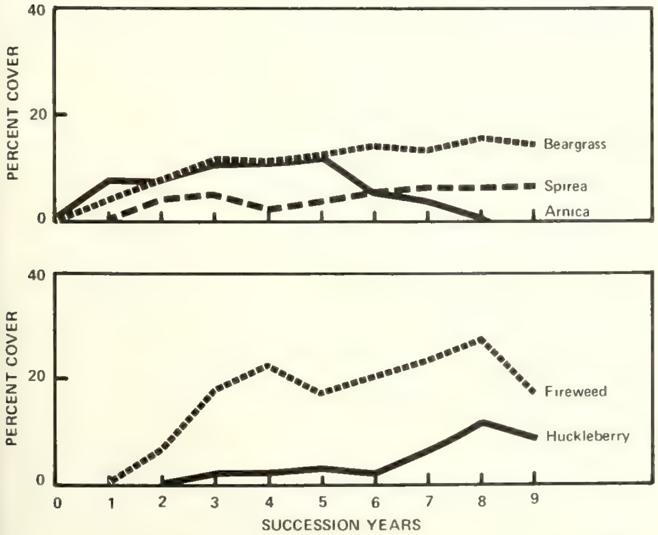

Figure 18.—Development of five prominent plant species following a low-intensity broadcast slash fire on Unit S-1 at Miller.

Plant succession on the wildfire unit also began with an herb stage dominated by fireweed and beargrass, but it was shorter in duration. A shrub component of spirea and Rocky Mountain maple *(Acer glabrum)* exceeded the herb cover by the sixth year (fig. 15), and 2 years later snowbrush ceanothus, a rapidly developing pioneer shrub, became the most abundant cover. Though blue huckleberry was the predominant species among preburn shrubs (with more than 50 percent cover), its postburn recovery has been exceedingly slow. It did not exceed 1 percent cover until the eighth year. Pioneer tree cover was composed of lodgepole pine and western larch. Both became evident as cover in the fourth year (fig. 15). During this initial development stage, the increase in tree cover has been slow relative to the shrub and herb components. While trees remain the least important, they have the potential to shortly displace the shrubs in the wildfire area.

RESPONSE TO BURNING

Some 75 plant species contributed to understory cover before and after burning on the studied units at Miller and Newman. Of these, 16 species accounted for most of the vegetation and thus set its character and mode of development. These principal species each had a cover value of 15 percent or more for at least a year. Principal species consisted of residents and immigrants. Pacific yew *(Taxus brevifolia)* was the only principal resident species eliminated by fire. Before treatment, this prominent tall shrub occurred on 80 percent of the units at Miller with coverage of 1 to 63 percent. After burning it failed to reappear on any of them. While all remaining principal resident species survived, their response to burning varied. The group that responded slowest, and has yet to regain its principal species status, includes the shrubs, rusty menziesia *(Menziesia ferruginea)* and Rocky Mountain maple, and the herbs, goldthread *(Coptis occidentalis)*. These are fire sensitive plants. Their survival was low, their redevelopment was slow, and their percent cover remains well below preburn levels. The more effective burning treatments reduce their survival and slow their response. A second group, including spirea (low shrub), pinegrass (fig. 19), northwestern sedge (both herbs), and twinflower (low woody plant), showed the opposite response. Fires of light to moderate intensity did not kill these plants, but created a favorable habitat for their postfire development. Increases in cover by the fifth to ninth year placed them well above preburn levels.

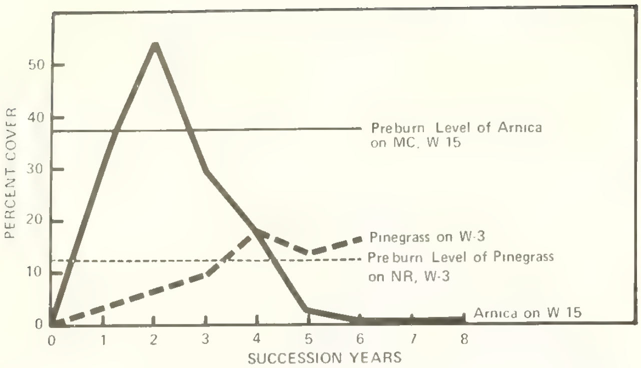

Figure 19.—Maximum development of two resident herbs (arnica and pinegrass) that commonly increase after fires.

Four resident species showed a mixed response to burning. Postfire coverage was higher than prefire coverage on some units and lower on others. In most instances, fire intensity accounts for these variations in response. Huckleberry, the only shrub occurring on all 20 units and present as a principal species on 70 percent of them, had an intermediate rate of cover development. On only two did it regain principal species status. Its recovery on half of the units was between 25 and 50 percent of prefire levels. Response of blue huckleberry to fire is discussed by Miller (1977).

Beargrass, with its surface rhizomes, is quite sensitive to fire. On burns in which the duff layer was left intact, its cover development exceeded preburn levels. But, on units on which fire removed or greatly reduced the duff layer, its cover development had not achieved preburn levels after 7 to 9 years.

Response pattern for thimbleberry is that of a pioneer shrub. It appeared as cover on 60 percent of the postburn units, which is almost twice as many as was its preburn occurrence. Its coverage was several times that of preburn levels on most units, and on two it reached principal species status during the 9 postburn years.

Broadleaf arnica (fig. 19) responded to fire with rapid initial growth during early postfire years, producing sharp increases in cover and an unusually abundant flower crop, usually in the second year. Then, after seed production, its cover declined and remained at low levels.

Two principal, essentially resident species did not survive the fire as living plants, but reestablished or maintained their presence in the community from seed. They are snowbrush ceanothus and lodgepole pine. Both are pioneer species characteristic of early seral stages of forest succession. Ceanothus was not present in the prefire vegetation on any of the units. After burning, it appeared in the first year as large numbers of new seedlings on six of the units. All these units had southerly exposures and all received highly effective (hot) burning treatments. Ceanothus has smooth, round, relatively heavy seed that precludes high mobility. It had to be present in the ground at the time of burning to produce the high seedling densities measured. Currently it represents the predominant plant cover on these six units and is largely responsible for their early entry into the shrub stage. On four units at Newman the cover development of ceanothus was evident in the first year due to high seedling densities (fig. 20). It continued to rapidly increase in cover through the sixth and seventh year (the last years of record), becoming the predominant cover plant in the fourth to seventh year. At Miller, ceanothus appeared only on areas burned in the wildfire. The pattern of development there was similar to Newman, differing mainly in a slower initial development. At Miller it was not detected as cover until the third year (fig. 20). Afterwards ceanothus grew rapidly, becoming the predominant cover in the eighth to ninth year.

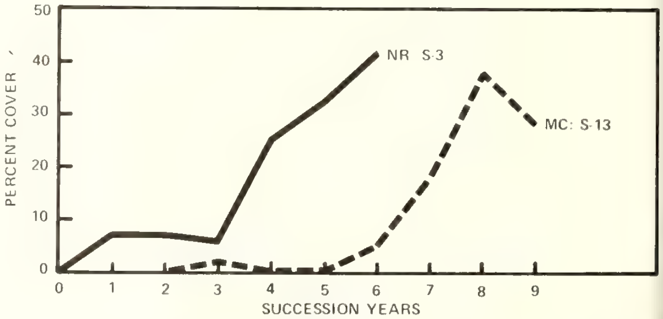

Figure 20.—Development of snowbrush ceanothus after wildfire in standing timber at Miller (S-13) compared to an intense broadcast slash fire at Newman (S-3).

Mature lodgepole pine trees were present on areas with standing timber burned by the wildfire. They provided the source for seedlings that appeared in the first postburn year. Relative to snowbrush ceanothus, cover development by lodgepole seedlings was very slow, reaching principal species status by the ninth year on only one unit.

Postburn vegetation contained three principal species that immigrated from outside the burned area. Fireweed, autumn willowweed, and Scouler willow were not found prior to burning. All three are pioneer species that have small, light, downy seeds that permit long distance airborne dispersal. Next to huckleberry, fireweed was the most widely distributed postburn species, occurring on all but one of the units. It was the most abundant early seral plant, consistently having greater cover during the herb stage than any other. The extent and magnitude of the herb stage is largely attributable to this species.

The greatest coverage of fireweed occurred at Miller on moist sites with very effective (hot) burns. Well-established stands on these favorable sites exhibited a distinct development pattern (unit E-6 in fig. 21). Following establishment in the first year after burning, its cover increased very rapidly, reaching maximum values by the second or third year. Thereafter, fireweed cover declined to less than half of peak values by the sixth year. On less favorable sites (drier conditions) the pattern differed; maximum cover values developed slowly and were not as high (unit S-1 in fig. 21).

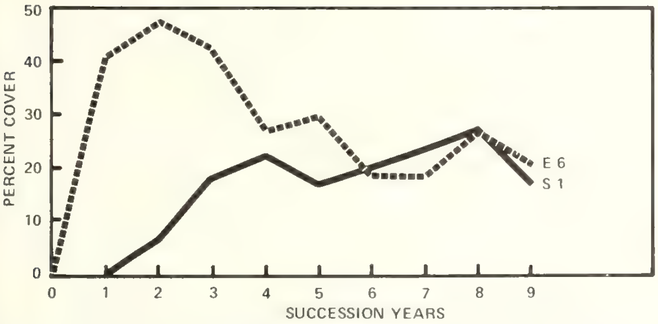

Figure 21.—Contrasting development patterns for fireweed at Miller following an intense slash fire (E-6) versus a low-intensity slash fire (S-1).

Autumn willowweed, a native annual, attained principal species status on only one unit and then for only 2 years. Characteristically, its occurrence as a cover species after fire is short, usually appearing in the second year and lasting 2 or 3 years. Thereafter it continues to be present but always at cover values less than 1 percent. Though brief in its successional appearance, it has the potential to make a significant contribution to vegetative cover in the first few years of succession when total plant cover is low. On the unit where it reached maximum cover in the second year, it provided the greatest amount of cover of any species.

Scouler willow was not found on any of the inventoried units before burning but its seedlings occurred on 80 percent of the units after burning. The rate of cover development by seedlings of this pioneer shrub is quite slow. It had reached the principal species level on only one unit by the ninth year. Earliest detection as cover varied from the second to the seventh year. Initial development is one of slow but continuous increase. After 6 to 9 years willow cover on all but two areas was less than 10 percent.

Figures 22, 23, and 24 illustrate the development of vegetative cover on several study units at Newman Ridge and Miller Creek.

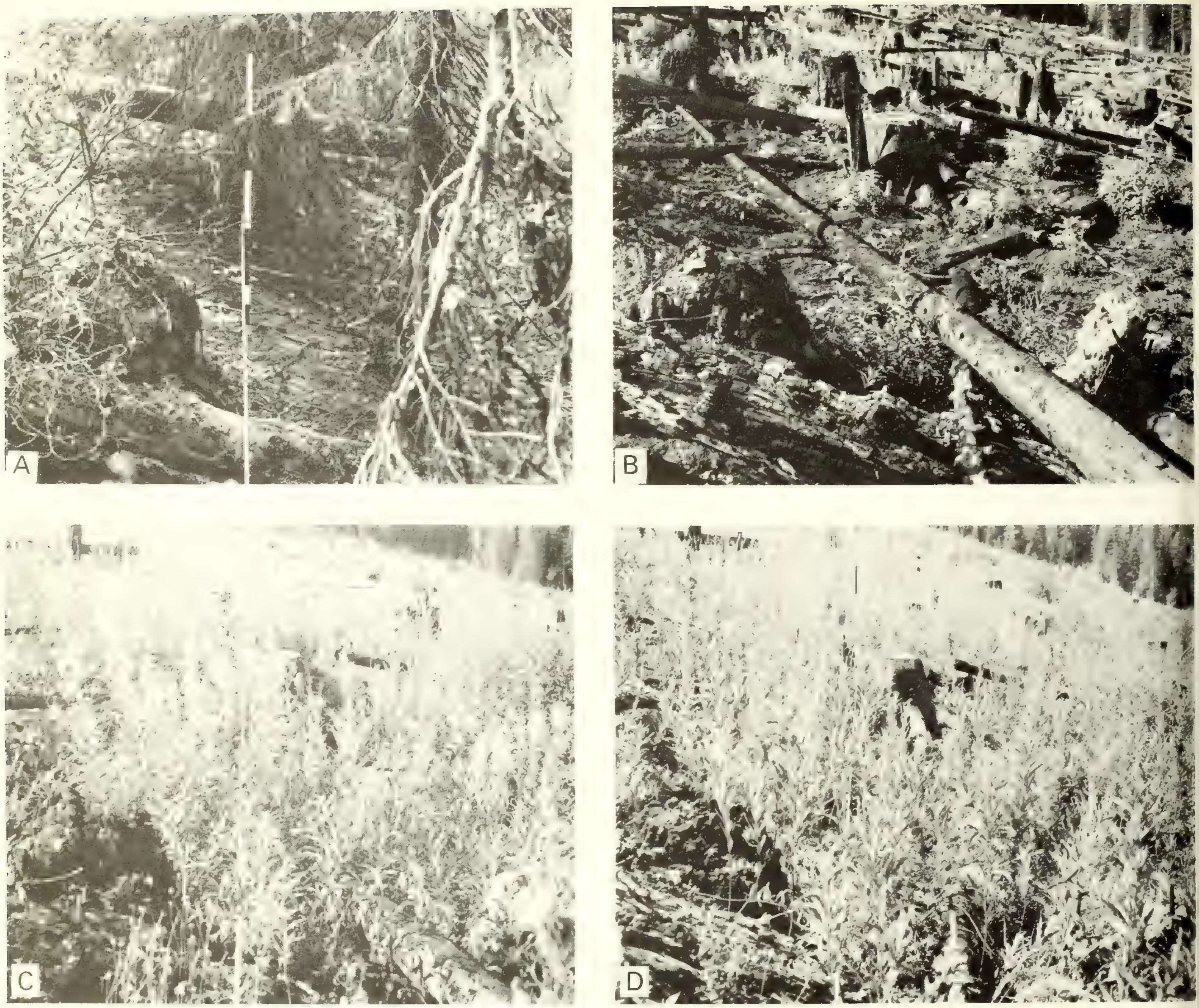

Figure 22.—Miller unit N-8 before treatment (a), 1 year after logging and broadcast burning (b), 2 years after (c), and 5 years after (d). Shrub development was slow; after 7 years (1975) this transect still appeared as it does in "d," with fireweed the dominant herb.

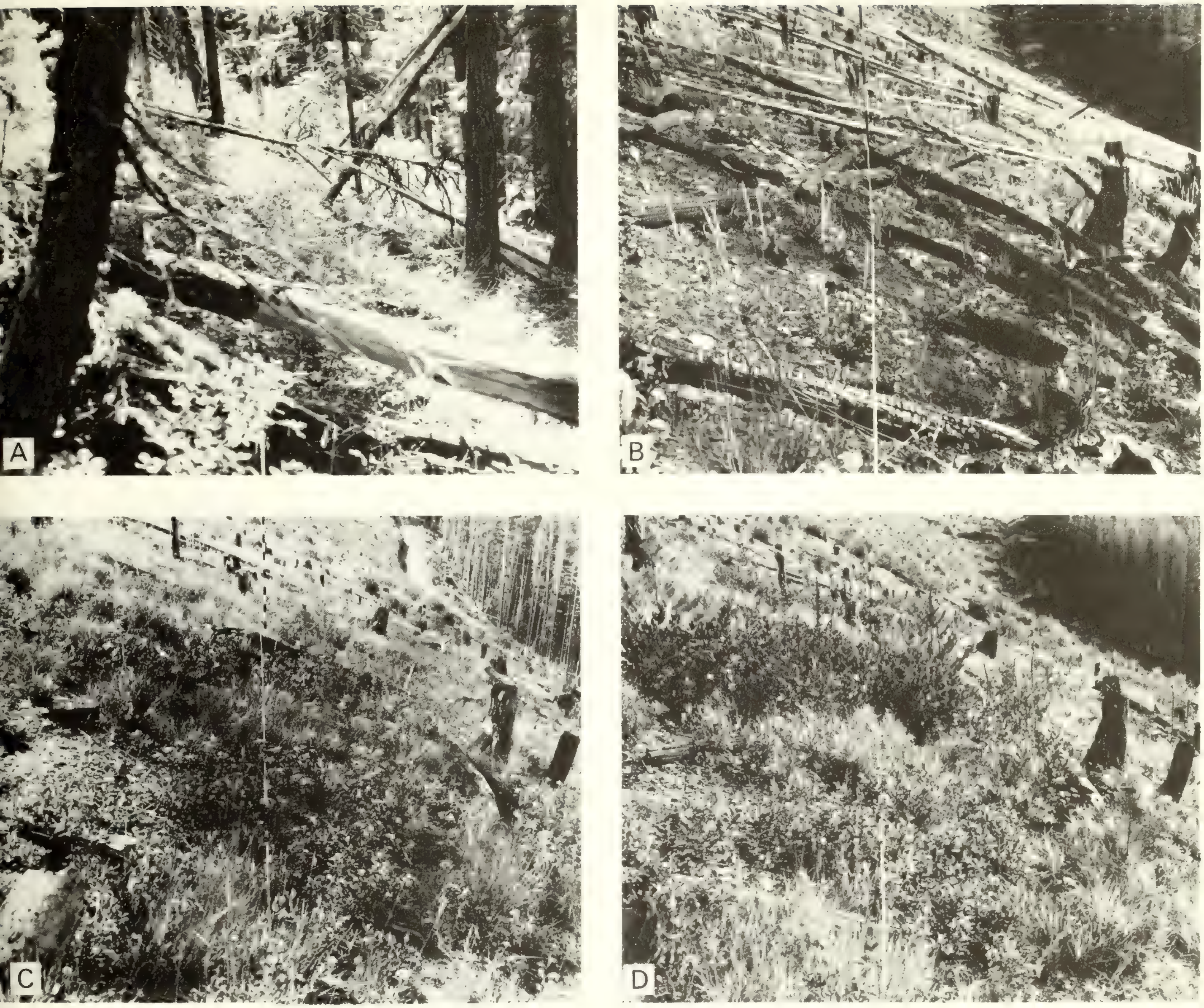

Figure 23.—Newman unit W-3 before treatment (a), 1 year after logging and broadcast burning (b), 4 years after (c), and 6 years after (d). Progression to the shrub stage is obvious in "d," with some tree seedlings also visible.

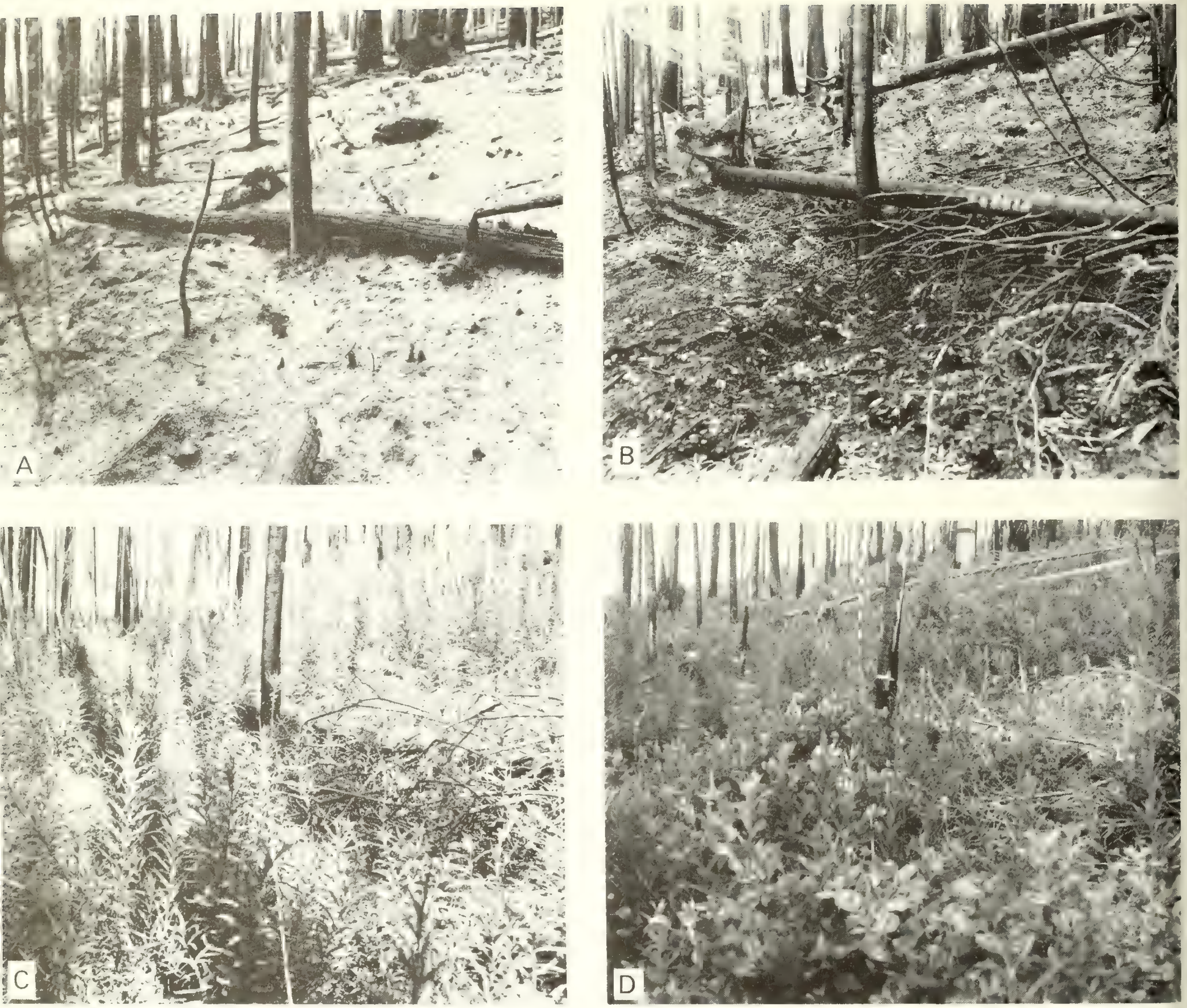

Figure 24.—Miller unit S-12 immediately after wildfire (a), 1 year later (b), 3 years after (c), and 8 years after (d). After passing through an early herb stage, dominated by fireweed, (c), succession to shrubs and trees was rapid on this area (d).

Long-tailed vole trapped on a clearcut unit at Newman. (USDI Fish and Wildlife Service photo)

Small Mammal Populations

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Small mammals, chiefly rodents, are the most numerous large primary consumers of plant energy. Their prediliction for conifer seeds and seedlings as food makes these rodents of interest to forest managers. Deer mice (*Peromyscus maniculatus*), chipmunks (*Utamias* spp.), and red-backed voles (*Clethrionomys gapperi*) are especially important consumers of conifer seed (Radvanyi 1973). Small mammals, most of which are active yearlong, usually have two or more litters per year. Young mature in 2 or 3 months; populations turn over rapidly. Population rotations, especially among mice, are only 9 to 18 months long. Some species are cyclic in numbers, apparently responding quickly to food increases, favorable habitat change, and weather effects. Small mammals live in a microclimate within 18 inches (46 cm) above the ground surface to somewhat below. A small rodent spends most of its life on less than an acre. Worldwide, small mammals are the most important food source for terrestrial carnivores—both birds and mammals. They may be important indicators of forest habitat condition.

Species composition and relative abundance of small mammals on selected units at Miller and Newman were determined and related to patterns of plant succession and cover conditions for several years after clearcutting and broadcast burning.

Of 11 small mammal species caught, the most common and abundant rodents at Newman and Miller were the deer mouse and the redtail chipmunk (*Eutamias ruficaudus*). They, along with the ermine (*Mustela erminea*) and vagrant shrew (*Sorex vagrans*) were found on all sites—undisturbed timber, logging slash, and light and severe burns. The ermine and shrew appeared in very small numbers, however. In terms of total individuals caught, deer mice, chipmunks, and red-backed voles constituted 90 percent of more than 1,800 small mammals caught on the two areas during the period 1967 through 1974. The red-backed vole did not have the same distribution as the other species, as will be discussed. These three rodents readily consume and store conifer seed; the vole is also adapted to using succulent vegetation.

SMALL MAMMAL POPULATIONS IN OLD-GROWTH TIMBER

The mature, uncut forest and its small mammal populations serve as the reference base to assess impacts of logging and burning. Figure 25 averages 6 years of live-trapping on the forested control plots on Newman. It includes the year of abundant conifer seed (1971), and the fluctuations in red-backed vole, chipmunk, and deer mouse numbers. This 6-year average catch, by species, illustrates the variation that may be expected in small mammal populations of old-growth larch/Douglas-fir stands.

The most abundant rodent in old-growth timber was the red-backed vole. In contrast, it was virtually absent on burned plots (fig. 25). Its relative stability and abundance on the north-facing plot suggests a very favorable environment. The red-backed vole is considered a forest species showing strong association with damp conditions (Getz 1968; Gunderson 1959; Odum 1944), as well as rotting log and stump cover (Gunderson 1959; Williams 1955).

The second most common timber inhabitant was the chipmunk, a rodent partial to some cover (Tevis 1956) and drier sites. Comparison of the 6-year means (fig. 25) shows chipmunks twice as common in the drier south timber plot. This is in keeping with its recognized habitat association.

Deer mice were an important component on all plots (fig. 25). But, like chipmunks, they were more common and their numbers varied less between years on the drier south aspect. Thus, they exhibited the same population response in their preferred (drier) environment as did the red-backed vole in its favored (wetter) habitat. Simply put, larger and more stable populations are found in preferred habitat. No other mouse or vole species were caught in the timber at Newman or at Miller. They were undetectable at the sampling level used. Their detection on burns (fig. 25) indicates that they must have been present, albeit sparsely, in the uncut forest, too.

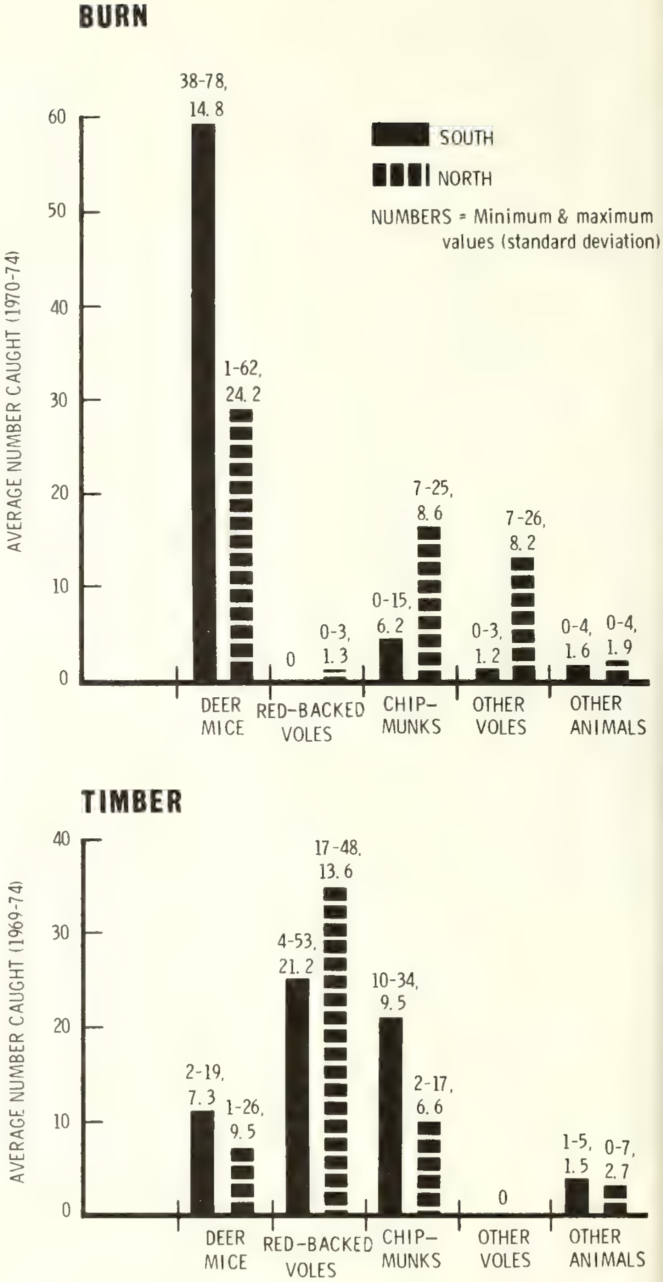


Figure 25.—Average number of small mammals caught at Newman. Uncut timber is compared to broadcast slash burned units on north (N-3) and south (S-3) aspects.

Other animals (fig. 25) appear in about equal numbers. The few that were caught merely indicate their presence. They include the ermine, vagrant shrew, northern flying squirrel (*Glaucomys sabrinus*), red squirrel (*Tamiasciurus hudsonicus*), and bushy-tailed woodrat (*Neotoma cinerea*). Three of these, the ermine, flying squirrel, and shrew, respectively, were 2, 3, and 10 times more often caught in the south-timber than in the north-timber plot at Newman. The flying squirrel's critical habitat includes nesting cavities in large and durable snags. Snags of western larch and ponderosa pine best embody these attributes of size and durability. The north-timber plot had no ponderosa pine whereas the south had both pine and larch.

Table 11 compares and summarizes the relative importance of small mammal species in old-growth timber at Newman and Miller. Even with the small Miller sample, the dominance of red-backed voles in timber is still obvious. A similar relationship within and between these widely separated study areas is also seen for chipmunks, deer mice, and "other voles." Within the complex, mature timber habitat, chipmunks were more common than deer mice, "other voles" were absent, and "other animals" were in greater abundance. Ninety percent of "other animals" at Miller were shrews.

POPULATION CHANGES AFTER CLEARCUTTING AND BURNING

Treatment resulted in marked and comparable changes in small mammal species composition at both Miller and Newman (table 11). Deer mice rose from less than 20 percent composition to over 70 percent. Red-backed voles disappeared. Other vole species, mostly the long-tailed vole (*Microtus longicaudus*), appeared in catches for the first time. Chipmunk presence was reduced by at least 30 percent.

Clearcutting a closed-canopy forest, broadcast burning residual slash and understory vegetation, and raising soil surface temperatures to over 500°F (260°C) are catastrophic changes to the small mammal habitat. Broadcast fires seldom persist very long, nor blanket an area uniformly, nor with an even intensity because of varying fuel distribution and moisture on clearcuts. There are hot and there are cool spots.

Table 11.—Comparison of small mammal species composition in uncut timber and clearcut burns on Newman (1969-74) and Miller (1967-74)

Species	Timber				Burn			
	Newman[1]		Miller[1]		Newman		Miller[2]	
	Percent	*No.*	*Percent*	*No.*	*Percent*	*No.*	*Percent*	*No.*
Deer mice	16	111	10	6	70	440	74	413
Chipmunks	26	183	25	15	16	104	8	42
Red-backed voles	52	356	44	27	1	3	2	14
Other voles	0	0	0	0	11	71	12	67
Other animals[3]	6	42	21	11	2	14	4	23
Totals	100	692	100	64	100	632	100	559

[1] All aspects combined, by treatment. Miller Creek is only a one-time (1967) sample.

[2] Does not include two unburned clearcut blocks.

[3] Shrew, ermine, flying squirrel, red squirrel, woodrat, and snowshoe hare (*Lepus americanus*).

Most rodents nest underground, sometimes several feet below the surface. Soil is an excellent insulator. Despite the 500°F (260°C) surface soil reading on the S-3 plot on Newman, subsurface temperatures at 2 inches were 118°F (60°C) (Ray Shearer, personal communication). Field experiments with caged rodents buried underground have shown the lethal level to be 140°F (60°C) (Howard and others 1959) to 121°F (49°C) at relative humidities below 50 percent (Lawrence 1966). Fire does not necessarily deny food to rodents, especially spermivores (seed-eaters), since caches and naturally fallen seed accumulated over time (such as from snowbrush ceanothus) or disseminated after the fire (such as from lodgepole pine) are available. Fungi, including hypogeous (subterranean) types, are always present and widely used by many small mammals (Maser and others 1978). Insects, an important food for many rodents, especially deer mice and shrews, quickly emerge after the fire or reinvade the site. Corms and bulbs virtually always survive fire, and rhizomes and root crowns usually do. All are postfire food sources.

Removal of the forest probably had the most profound effect on mammals; fire was of secondary importance. Unfortunately, the study design did not allow a clear distinction between the effects of forest removal and the effects of fire. Clearcutting drastically altered arboreal nesting habitat, removed much escape cover and physical shelter, and changed the microclimate (humidity, surface temperature, soil moisture, and wind movement) in the zone occupied by small mammals.

The N-3 and S-3 units on Newman provide some insight into the effects of fire intensity. Unit S-3 burned hot and clean in mid-September, whereas unit N-3 burned poorly only 2 weeks later. Only 35 percent of the surface of N-3 was touched by fire. Wet duff kept the burn relatively cool. So, the most pronounced environmental effects on S-3 were the result of clearcutting plus a hot slash fire, while those on N-3 were largely the result of clearcutting and minimally that of fire. Rodent trapping was being done on the adjacent timbered control plot when S-3 was burned. Trapping began 2 weeks later on the burned units.

Ninety-five percent of the animals caught on S-3 (the hotly burned unit) in the first 3 years were deer mice (fig. 26). As cover developed a few chipmunks and other mouse species moved in, but they never exceeded 10 percent of the catch. It is important to note that all rodents caught on S-3 two weeks after burning were deer mice. Their populations in adjacent timbered areas were extremely low at the time, strongly suggesting that large numbers of deer mice were present in the year-old slash on S-3 and that they survived the fire in place. Densities varied from 6 to 12 per acre. Deer mice are a pioneering species strongly associated with seral situations (Williams 1955).

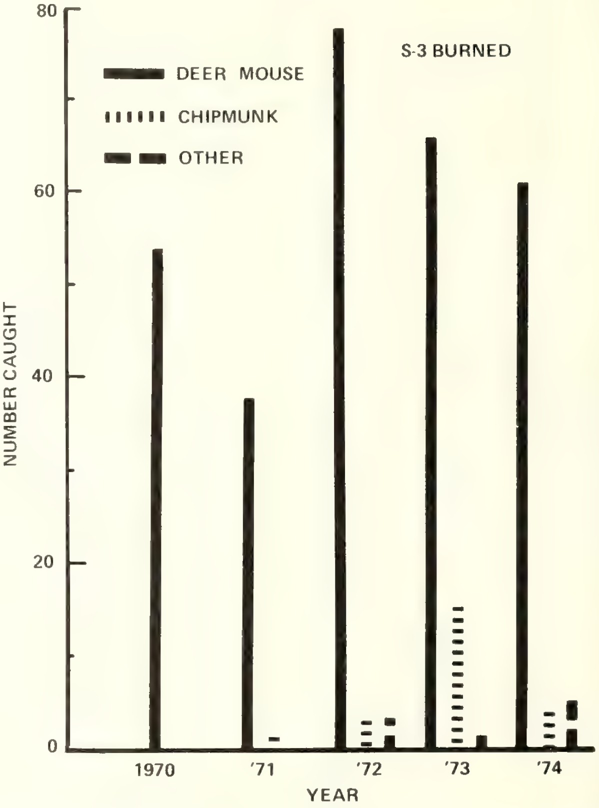


Figure 26.—Numbers of small mammals caught, by species and years, on unit S-3 at Newman. Logged in June 1969, intense slash fire in September 1970.

By contrast, deer mice on the cooler burned unit (N-3) have been of lesser relative importance, although they were still the most abundant rodent caught (figs. 25 and 27). The N-3 burn provided a diversified environment, including moist shaded areas, a variety of forbs and fruit, and seedbearing shrubs. Under these conditions, population growth of deer mice was likely restrained by competition from other species occupying niches in the less disturbed habitat on N-3.

Chipmunks were an important part of the catch on unit N-3, even at the time of the fire. After burning, abundant slash remained on N-3. Chipmunks favor cover (Tevis 1956) and, no doubt, preferred this area. Their increase is associated with increasing cover and with fruit and seed producing plants (Gashwiler 1970; fig. 27). The catch averaged over twice that for S-3 in the 1970-74 period (fig. 25).

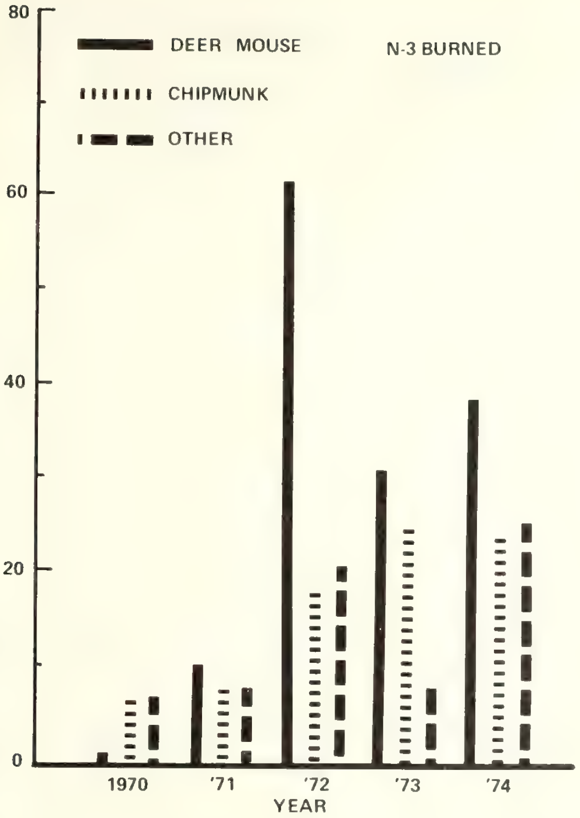


Figure 27.—Numbers of small mammals caught, by species and years, on unit N-3 at Newman. Logged in June 1969, low-intensity slash fire in September 1970.

Long-tailed voles have been the only other mouse-like rodent to appear on unit N-3 (fig. 25). Their occurrence on N-3 apparently results from the existence of the moist sites, where most of them were captured. Habits of this rodent are not well known (Maser and Storm 1970) but it probably is more of a grazer on succulent vegetation than a seed-eater. It was never caught in timber (fig. 25), which suggests that it may be an unsuccessful competitor with the red-backed vole.

The Newman burns (N-3 and S-3) had lower rodent numbers the first 2 years, but since then rodent populations in these units consistently exceeded populations in adjacent timber (fig. 28). The north unit, initially with the lowest catches of any, still had a growing population some 7 years later. Though not proven, the reasons for the population increase after cutting and burning probably are the cumulative effects of more habitat niches, which resulted in a diversity of rodent species, plus development of a vigorous understory flora, which, in turn, responded to release by clearcutting and to the fertilizing effects of leached ash (Ahlgren and Ahlgren 1960; DeByle 1976).

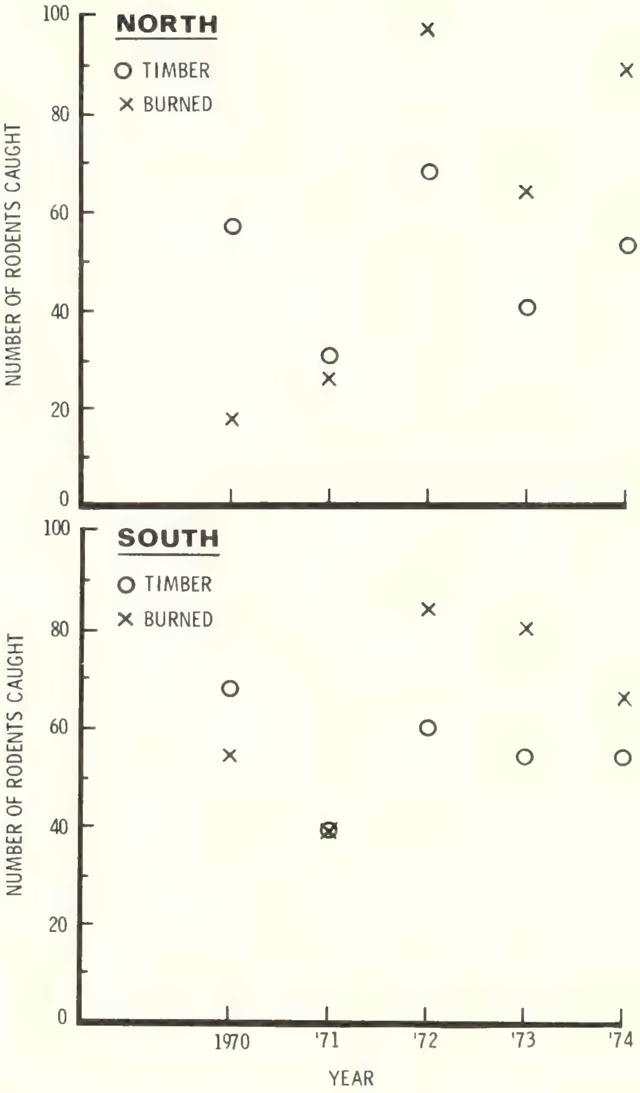


Figure 28.—Annual rodent catch for north and south aspects at Newman, comparing old-growth timber habitat to clearcut and burned habitat.

Rodent numbers were also influenced by a nonfire effect that should be recognized by forest managers who attempt forest regeneration. In the 1969-74 period at Newman the largest catches were in 1972 (figs. 26, 27, and 28), with deer mice (fig. 29) making up the bulk of the catch. A heavy seedfall occurred in 1971 (Shearer 1976 and in this report). The subsequent rodent increase corresponds to previous reports (Jameson 1953; Gashwiler 1966; Hooven 1976) that deer mice increase the year following a heavy conifer seed year.

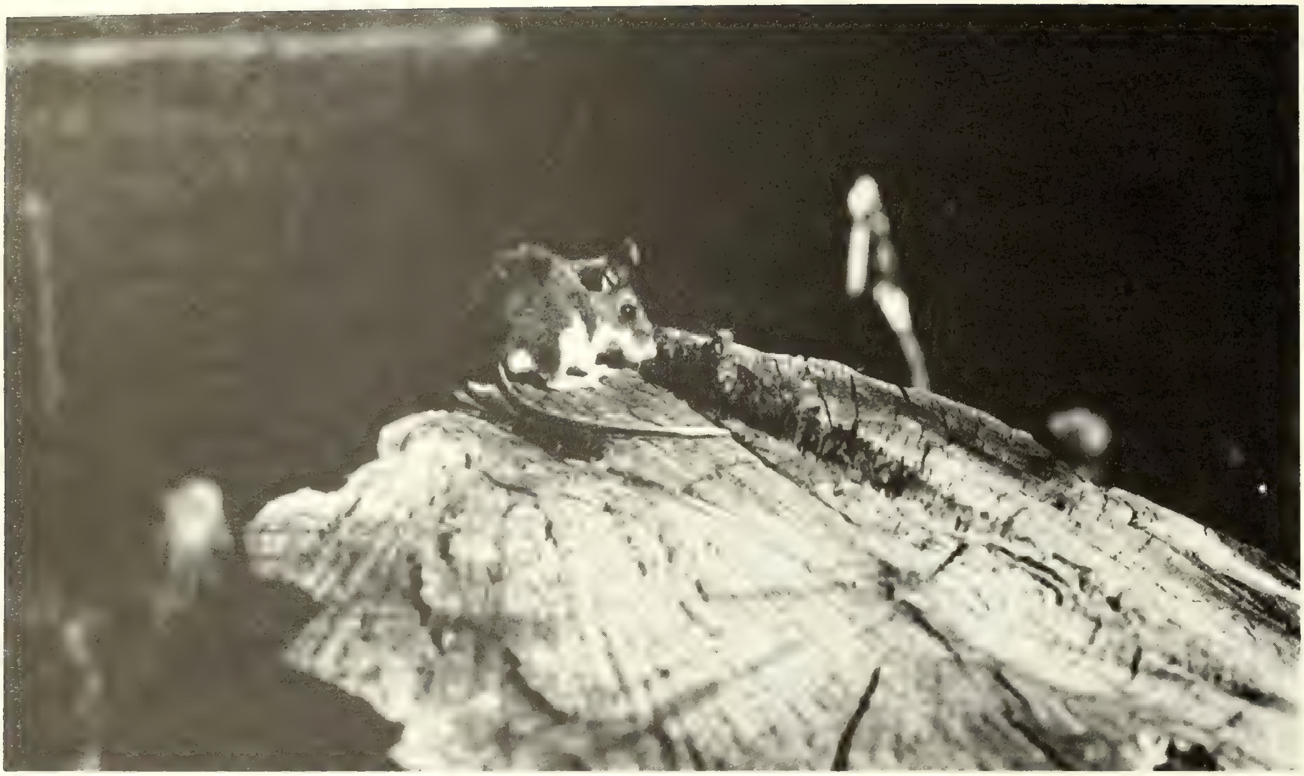
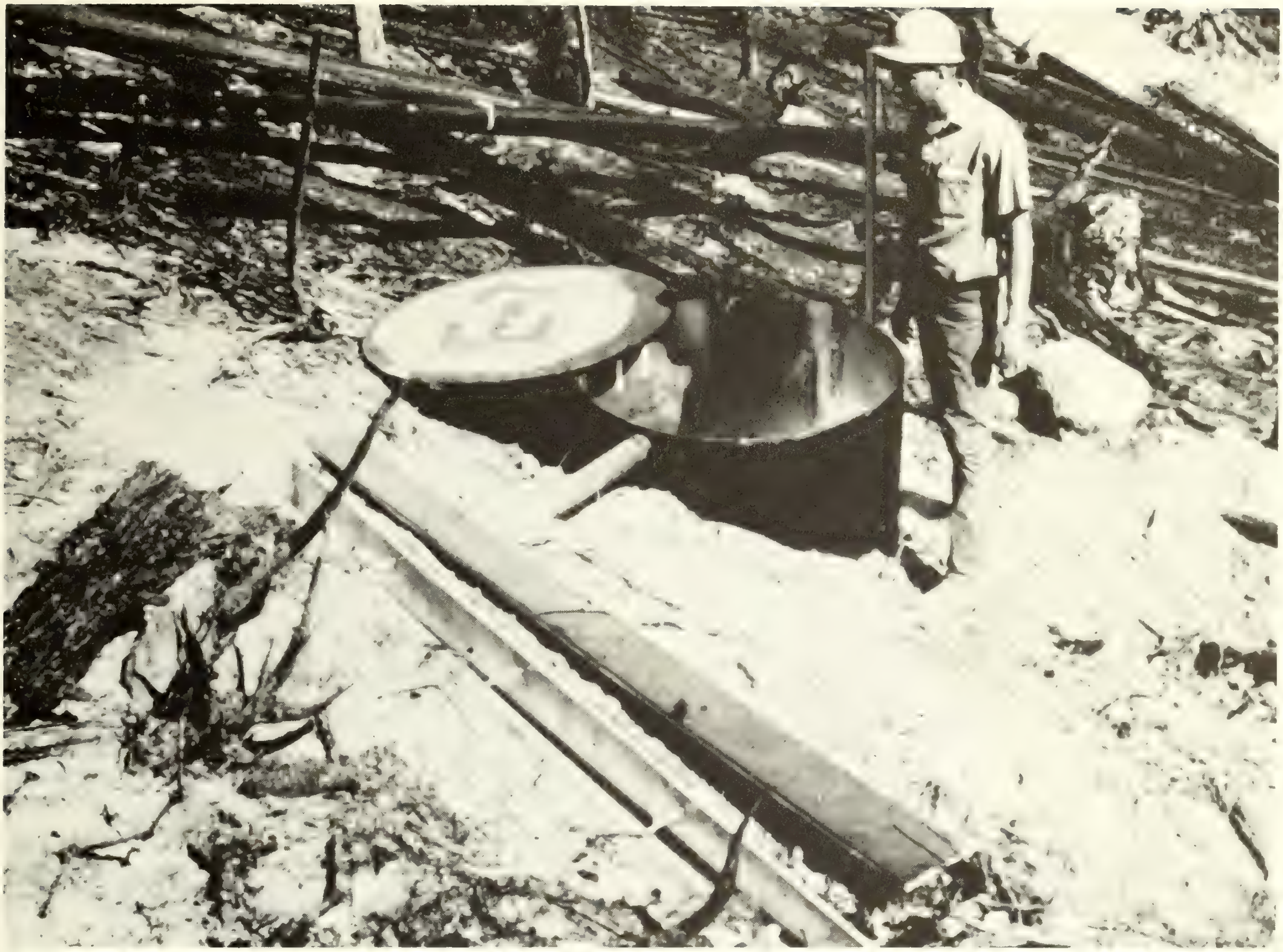


Figure 29.—Deer mice are the most common seed-eating rodent during early years of succession after clearcutting and broadcast burning. (Photo by Halvorson, USDI Fish and Wildlife Service.)



Catchment trough and storage tank installed immediately after burning at the base of a runoff plot at Miller.

Soils and Watershed

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When plant cover is sufficient on these humid watershed lands, very little of the annual precipitation becomes overland flow. Seepage flow through these soils does not adversely affect slope stability, even where steep, as on Newman. Baring of mineral soil surfaces through logging disturbance, fire, road building, or any other process sets the stage for overland flow and erosion of soil and nutrients from these slopes. The effects of clearcutting and burning on soil physical properties, quantity and quality of overland flow, and amount and nutrient content of eroded material were measured for several years on small runoff plots on both study areas.

The annual cycling of plant nutrients is temporarily interrupted by removing much of the plant cover (clearcutting) and then killing what remains (burning). Also, burning converts the nutrients held in the fuels to gaseous products (such as NO_2) or ash. The ash, then, is readily leached of many of these nutrient elements by subsequent rainfall or percolating water from snowmelt. The effects of these processes, as reflected in soil chemical properties, were measured for several years at Miller. The material presented in this chapter summarizes prior publications by these authors, particularly those by DeByle (1976) and Packer and Williams (1976) in the proceedings of the Tall Timbers Fire Ecology Conference No. 14.

PHYSICAL SOIL PARAMETERS

Cover

Before treatment, the mineral soil surface was protected from direct raindrop impact and erosion by a complete blanket or organic material (A_o horizon) as well as a vegetative canopy. Logging removed the canopy and partially broke up the organic matter blanket.

Burning dramatically decreased total soil cover to less than 50 percent on all the Miller runoff plots. These reductions were greatest on south aspects, which were driest and usually supported the most effective fire. On these plots, a slight decline continued during the first year after burning to less than 40 percent cover. Recovery then was rapid, with herbaceous vegetation, particularly fireweed, making up most of the cover. Between 3 years and 7 years after burning, total cover declined, partly due to a decrease in fireweed. By the seventh year about two-thirds of the soil was protected with vegetation or litter (fig. 30). Perennial vegetation and litter 10 years after treatment appeared to cover at least 75 percent of the ground on these study areas.

Burning decreased the cover to less than 20 percent on the Newman runoff plots. Again, reductions were greatest on south aspects. Following a flush in vegetation growth during the first year after burning and a decline in the second year, recovery of vegetation was rapid and reached about 65 percent by the fifth year after burning.

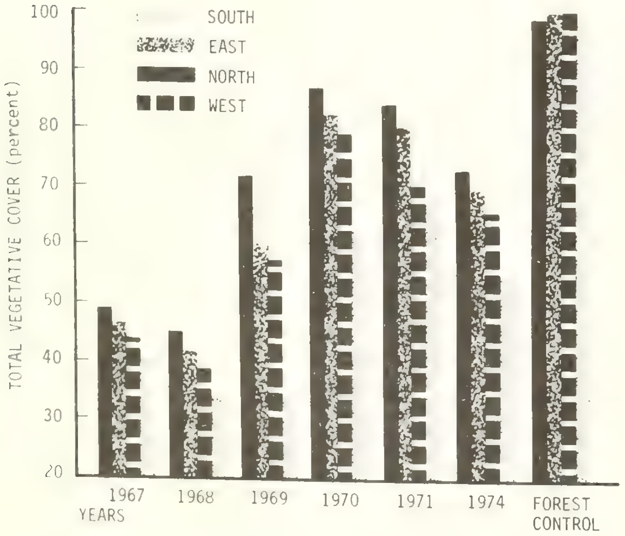

Figure 30.—Effect of logging and broadcast burning on total vegetative cover through 7 postburn years at Miller.

Organic Matter Content

At Miller, logging significantly increased organic matter in the surface inch (25 mm) of soil (fig. 31). Burning decreased it. Organic matter continued to decrease on the runoff plots and on the intensely burned areas for the next 2 years. This postburn decline is partially attributed to wind and water erosion but primarily to decomposition of the residual organic matter during the denuded period following fire, when annual increments of organic debris were negligible. Recovery on lightly burned areas began to occur the first year after burning. On the intensely burned areas and on the runoff plots it began 2 years after burning. The organic matter content of the soil was not affected significantly by logging or burning below a sampled depth of an inch or two (25-50 mm).

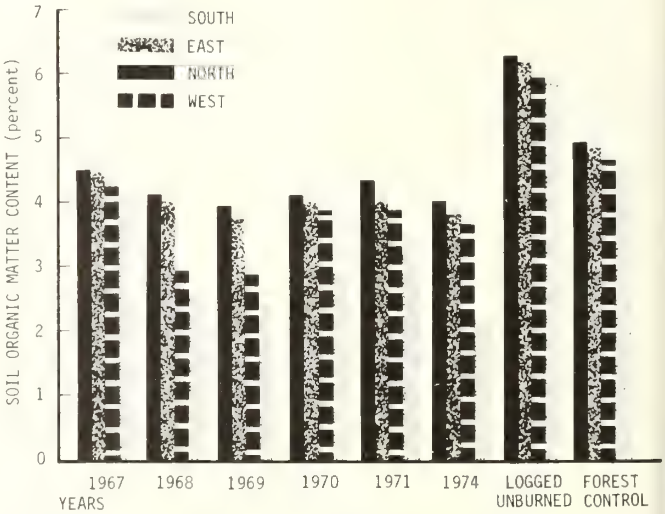

Figure 31.—Effect of logging and broadcast burning on organic matter content of the surface inch of mineral soil at Miller.

At Newman, logging increased organic matter in the surface inch (25 mm) of soil. Again, burning decreased it. During the first year after burning, organic matter increased along with the flush in vegetation, but again declined during the second year. Since then, through the fifth year after burning, organic matter remained almost constant at about 5.2 percent, nearly that on the unlogged, unburned sites.

Porosity and Bulk Density

At Miller, greatest soil bulk density and lowest porosity values were found on the south aspect, with a decreasing trend in density and increase in porosity to west to east to north. These differences existed on both treated and untreated plots; they apparently were not caused by either logging or fire. Bulk density decreased significantly on all aspects following logging (fig. 32), probably from incorporation of fine logging residue into the soil surface. Burning had the opposite effect, increasing bulk density on all aspects. This likely was caused by partial combustion of some of the fine organic materials previously incorporated into the mineral soil. During the subsequent 4 years soil bulk density increased still further before reversing and recovering to bulk density values similar to logged but unburned plots in the first year. The smallest decrease, and hence the poorest recovery, has occurred on south slopes.

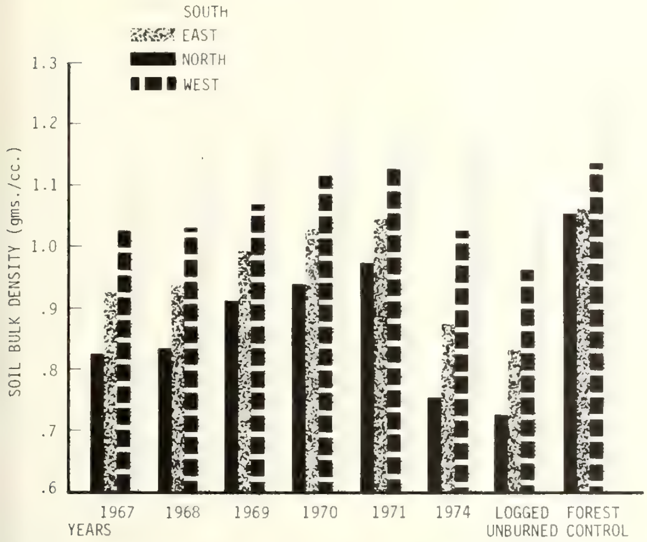

Figure 32.—Effect of logging and broadcast burning on the bulk density of the surface inch of soil at Miller.

At Newman, soil bulk density was highest and porosity lowest on the west aspect, with a decreasing trend in density to south to east to north. Bulk density decreased with logging, increased during the first 2 years after burning, and then decreased to its lowest value 5 years after burning. Poorest recovery has been on west and south slopes.

At Miller, logging increased soil porosity, no doubt for the same reason that it decreased bulk density. Burning reduced soil porosity, and it continued to decrease for the next 4 years toward prelogging and burning values. Subsequently this trend reversed and soil porosity increased to greater than prelogging values on all but the south aspects. There it has decreased continuously since the first posttreatment year.

At Newman, soil porosity increased with logging, decreased during the first 2 years after burning, and then increased gradually over the next 3 years. At the end of 5 years it was very nearly the same as porosity on the timbered control plots. Lowest porosities existed on west aspects in the fifth year after burning.

Water Repellency

The decomposing portion of the surface organic horizon (the lower strata filled with fungal hyphae) was very water repellent when dry in midsummer. However, the underlying mineral soil was only occasionally repellent, with most repellency at the interface between the A_0 and A_1 horizons. At least at Miller there was a temporary increase in the percentage of mineral soil samples found repellent after fire, particularly under intense burns. This repellency, however, was lost within a couple years. Fewer mineral soil samples were repellent 1 and 2 years after treatment than were repellent prior to burning.

Broadcast burning of logging debris over a relatively wet soil mantle does not cause sufficient heating of the mineral soil to produce a strongly repellent layer. Furthermore, the high clay content in these particular soils prevented serious repellency even where high enough temperatures were attained. Water repellency in the surface organic mantle does not appear to have practical hydrologic significance on these areas, as there is negligible overland flow and no erosion from the undisturbed forest areas where the organic layer is almost continuous and is thickest.

CHEMICAL SOIL PARAMETERS

The chemical parameters analyzed in the surface foot (30 cm) of soil at Miller before burning, after burning, and for 2 years thereafter are: pH; total contents of nitrogen, phosphorus, potassium, sodium, calcium, and magnesium; available phosphorus; cation exchange capacity; and exchangeable and soluble potassium, sodium, calcium, and magnesium.

Soil pH

Soils are acid, which is typical of the northern coniferous forest. Preburn pH was:

Soil depth		**pH**
Inches	*(cm)*	
0-2	(0-5)	5.6
2-4	(5-10)	5.8
4-8	(10-20)	6.0
8-12	(20-30)	6.1

Burning increased pH in the surface layers. The increase continued during the subsequent year. A year after burning, pH was 6.0 or higher at all depths.

Total Nitrogen

The organic fraction contains most soil nitrogen. The organic material on the surface or incorporated into the surface 2 inches (10 cm) of these soils contained 1 percent nitrogen by weight. Combustion of this organic material volatilizes much of this nitrogen. Nitrogen in the surface organic horizon (A_o) was reduced from 60 g/m^2 before burning to 40 g/m^2 after burning. A year later it had declined to 36 g/m^2. Thus more than a third of the nitrogen held in the organic layer was lost directly or indirectly by burning. The nitrogen content of the mineral soil was not altered by burning or during the following year. It remained at approximately 1.0 percent in the surface 2 inches (5 cm) and at 0.08 percent in the 2- to 4-inch (5-10 cm) layer.

Phosphorus

Total phosphorus content of the surface organic layer increased from 5.6 g/m^2 to 6.5 g/m^2 after burning. This increase probably came from ash-fall from burned logging debris. Leaching and erosion during the subsequent year reduced phosphorus content to 4 g/m^2. During the same time there was a slight increase in available phosphorus in the mineral soil, from 78 ppm to 84 ppm in the surface 2 inches (5 cm).

Potassium

The potassium content of the surface organic layer was 14.7 g/m^2 before burning. Ash-fall from burning increased this to 19.6 g/m^2. During the subsequent year more than half of this highly mobile element was lost from the surface layer of organic matter and ash, reducing the content to 8.8 g/m^2. At the same time, the exchangeable potassium content in the mineral soil increased as follows:

Soil depths		**Preburn**	**1-yr postburn**
Inches	*(cm)*	*Meq/100 g*	
0-2	(0-5)	0.38	0.47
2-4	(5-10)	.35	.44
4-8	(10-20)	.32	.36
8-12	(20-30)	.23	.26

Sodium

These soils contain comparatively small amounts of sodium. The surface organic layer contained 2.8, 2.9, and 2.1 g/m^2 before burning, after burning, and a year after burning, respectively. Neither burning nor the conditions the following year caused any significant change in the amount of exchangeable sodium in the mineral soil, but did cause a significant decrease in the amount of soluble sodium.

Calcium

Calcium was the most abundant cation in the surface organic horizon or in the mineral soil. It averaged 72 g/m^2 in the surface organic layer before burning. A year later there was 66 g/m^2, statistically the same as before. Exchangeable calcium content of the mineral soil did not statistically change after treatment. Variation among samples was much too great even to infer any possible trends. Soluble calcium in the mineral soil declined slightly during the year after burning, from 0.24 meq/100 g in the surface 2 inches (5 cm) to 0.20 a year later. The minute soluble contents of other cations similarly decreased in the mineral soil, too.

Magnesium

Total magnesium content of the surface organic horizon averaged 15.4 g/m^2 before burning but only 8 g/m^2 a year later. Almost half had been removed by leaching, erosion, or plant uptake. Exchangeable magnesium increased significantly during the first postburn year in the surface 4 inches (10 cm) of mineral soil.

Cation Exchange Capacity

The cation exchange capacity of the mineral soil did not change as a result of treatment. It remained near 20 meq/100 g in the surface 2 inches (5 cm) and decreased progressively to approximately 15 meq/100 g in the lower depths. The percentage of this exchange saturated with the four measured cations (Ca, Mg, K, and Na) increased slightly from preburn to a year postburn, from about 38 to 40 percent in the surface 2 inches (5 cm) with similar changes at lower depths.

WATER

The quantity and nutrient contents of overland flow from both spring snowmelt runoff and summer storms were determined for several years using data collected from the 24 runoff plots (12 on each area).

Amount of Overland Flow and Soil Erosion

At Miller, overland flow from snowmelt was negligible the first year after burning, but only 12 inches (305 mm) precipitation was received that winter. Increased precipitation, from 17 to 33 inches (430 to 835 mm), in subsequent winters produced overland flow from the timbered control plots as well as the treated units. None of the control plots produced any soil erosion from snowmelt runoff (fig. 33). Soil erosion from the logged-burned plots averaged 56 lb/acre (63 kg/ha) the first year after burning, then increased to 168 lb/acre (188 kg/ha) the second year, when 18 inches (455 mm) winter precipitation was received. By the third year, soil erosion from snowmelt decreased to 15 lb/acre (17 kg/ha) despite precipitation and overland flow being almost as great as it had been the previous year. Seven years after burning, when more winter precipitation was received than in any previous year, there was no soil erosion from these treated plots.

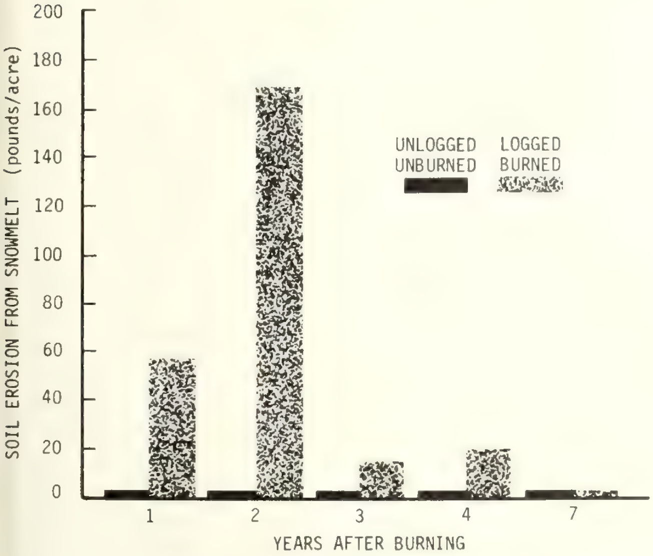

Figure 33.—Soil erosion from snowmelt overland flow for 7 years after logging and burning at Miller.

Overland flow from summer storms at Miller was much less than from snowmelt. Less than 0.2 inch (5 mm) ran off the treated plots during the first year after burning, when 12 inches (305 mm) precipitation was received. However, this small amount of overland flow produced 151 lb/acre (169 kg/ha) of sediment. Both overland flow and soil erosion declined dramatically in subsequent years (fig. 34). It is of interest to note that the largest amounts of soil erosion from summer storms and from spring runoff are almost equal—151 and 168 lb/acre (169 and 188 kg/ha), respectively. Yet, the summer storm flow (0.15 inch or 4 mm) that produced this amount of erosion was only 27 percent of the flow from snowmelt (0.55 inch or 14 mm). The more intense summer storms provide a much more efficient eroding force than does snowmelt runoff.

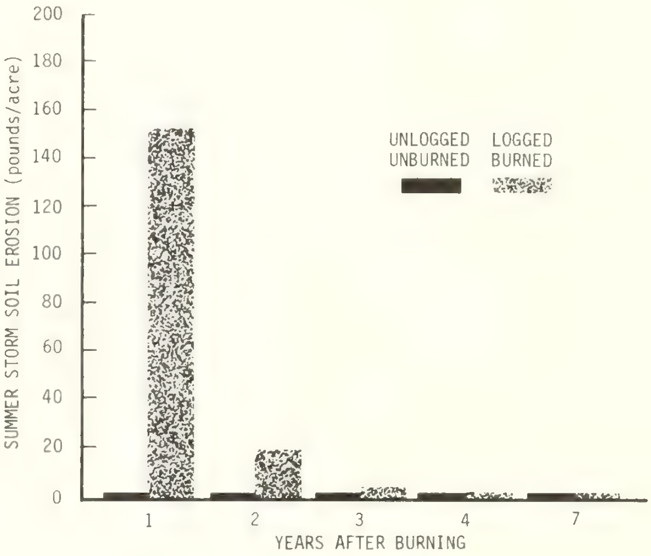

Figure 34.—Soil erosion from summer rainstorms for 7 years after logging and burning at Miller.

The records from the steeper slopes at Newman show a similar pattern. During the first 2 years after treatment less than 50 lb/acre (56 kg/ha) of soil had eroded from the burned plots as a result of snowmelt runoff. At Newman more than 10 inches (254 mm) of precipitation was recorded during the first summer after treatment and only 3 inches (76 mm) during the second summer. The overland flow resulting from this followed a similar pattern. No soil erosion was experienced from the control plots at Newman. But, during the first year after burning, erosion losses were 1,700 lb/acre (1 905 kg/ha) from the treated plots, primarily from one high-intensity summer storm. During the second year it was less than 20 lb/acre (22 kg/ha).

Nutrient Content of Runoff Water and Sediment

The organic matter content of the sediment from Miller ranged from 12 to 44 percent and that from Newman from 14 to 40 percent, much greater than the organic matter content of the surface mineral soil. The nutrients lost in this sediment at Miller declined from 11 lb/acre (12 kg/ha) during the first year to one-half lb/acre (0.6 kg/ha) during the fourth year after burning, and from 44 lb/acre (49 kg/ha) during the first year after treatment at Newman to only 1 lb/acre (1 kg/ha) the second year.

Runoff, like eroded soil, carried nutrients from the plots somewhat in proportion to its total quantity. However, the concentration of dissolved components in the runoff was especially high in the first year due to a flush of soluble materials from the ash on the burned plots.

The combined losses of components measured in both water and sediment decreased rapidly from the treated plots, and approached pretreatment losses within a few years. All nutrients lost from control plots were dissolved in the runoff water, as no soil erosion was experienced. From the treated plots at Miller, 42 percent of the 28 lb/acre (31 kg/ha) loss of nutrients (total of P, K, Ca, Mg, and Na) was dissolved in the surface runoff. The dissolved portion in the losses from Newman was less, only 20 percent of the total in the 2 years of measurement, largely because of the large amount of sediment produced in the first year after treatment.

Beaufait and Packer on a runoff plot at Miller surveying the vegetation, most of which is fireweed, that developed during the 6 years following logging and broadcast burning.

Uncut forest in the stream bottom and several south-facing burned units on the background hillside at Miller. Units S-12 and -13 (those with standing dead trees in right background) and several slashed units were burned in an August 1967 wildfire.

DISCUSSION AND MANAGEMENT IMPLICATIONS

Interpretation and management implications of the Miller-Newman research for each resource or discipline are presented in the same sequence as they appear in the Results section. Although interactions among the disciplines are discussed, it is not possible to quantify them. The Miller-Newman research was designed to quantify the effects of clearcutting and fire on each resource separately, not to combine resources into an analysis of variance. Hence, the interpretation of interactions among resources is subjective and somewhat speculative.

Fire Behavior and Effects

The techniques and prescriptions for use of broadcast prescribed fire in this forest type are developed to a degree that guidelines, such as those in appendix B, can be presented. Fire now may be used as a forest management tool with sufficient precision to predict and control its outcome with respect to several resources—water, soil, wildlife, vegetation development, forest regeneration, and air quality. Effects of the combined treatment (clearcutting and broadcast slash burning) have been quantified for these resources, in the Miller-Newman study. For most resources, this quantification includes fires that range the entire gamut of intensity and effectiveness. In addition, for some resources a comparison on adjacent units is made between the effects of wildfire in standing timber and clearcutting and broadcast slash burning. The methods and results of the fire phase of the Miller-Newman study were presented in detail by Beaufait and others (1977), and the management applications of this research were combined with the results of later work and presented in the Results and appendix of this paper. In short—here is the tool, here is how it can be used with precision, and here are the effects on individual resources. The management implications of these effects follow.

Smoke Management

The emission products from forest fires mix with and pollute the air. This pollution is inevitable. However, with knowledgeable use of prescribed fire, the timing of that pollution, the quantity and ratios of the pollutants emitted, and the volume and location of the polluted air are all under man's control. With these controls in mind, fire managers can make use of several salient results from the Miller-Newman study.

It has been known for some time that atmospheric conditions, particularly the height of free air convection and the velocity and direction of surface winds, influence smoke dispersion. However, in this study, fire intensity was found to have an overriding control on the height of convection columns and the elevation at which smoke plumes are dispersed. Also pointed out is the need for local weather forecasts, particularly for wind direction and velocity.

Particulates are present in the air for many miles downwind from forest fires. This particulate matter at the ground level, where people live, may be aerosols in smoke that has crept along the surface from a low-intensity fire, or it may be fallout of larger particles from a high-elevation smoke plume resulting from an intense fire. Both will be detected at air monitoring stations; but their air pollution effects are quite different. Aerosols in a smoke plume truly pollute the ground-level air with particulates and other emissions. In contrast, when fallout of larger particulates occurs, the air remains relatively clean, but the ground surface and any objects of man on that surface (automobiles, laundry on clotheslines, etc.) become dusted with ash. The study points out that ground-level downwind effects may be detected only on days with fires, not on subsequent days.

The water content of fuel controls fire intensity and the products of emission. Dry fuels and atmospheric conditions that result in a fast and intense fire produce the least particulate matter and carbon monoxide and the greatest amount of carbon dioxide for the quantity of fuel burned. Even though the total quantity of emissions from an intense fire may be less, the concentration in the smoke plume for several miles downwind from that fire may be great enough to obstruct air navigation.

Ideally, the smoke plume should be pushed upwards into an atmospheric layer not influenced by local air inversions, and thereby not likely to cause local air pollution at ground level. There the particulate aerosols and gases will move downwind at the speed and direction of upper level winds. They will remain at that level until atmospheric mixing disperses these pollutants. The particulate aerosols later will return to earth as condensation nuclei in precipitation.

Particulate matter is the primary pollutant in smoke from forest fires. The fires conducted at Miller and Newman produced approximately 30 pounds of airborne particulate per ton (15 kg/t) of fuel consumed. Management of fire intensity and timing will control the location and impact of that pollutant load.

Silviculture

Timing of prescribed fires to achieve satisfactory site preparation for silvicultural purposes is critical. Fires in spring or early summer usually burn over a wet duff layer and therefore bare little mineral soil. Following dry summers, late summer or early fall fires more effectively remove the duff layer and expose adequate mineral soil for forest regeneration. Even then, fuels and duff must dry for several days following significant precipitation. Conditions under which north slopes can be burned to substantially reduce the duff layer usually occur only in August and early September in the larch/Douglas-fir forest type. On other aspects there is more opportunity to broadcast burn logging slash and provide seedbeds.

High-intensity fires over a dry duff layer usually are unnecessary and often undesirable on mesic sites. These fires expose a high proportion of mineral soil. If a good seed crop follows, dense overstocking of tree seedlings will result. The moderate-intensity fires at Newman generated enough heat to consume most of the relatively dry duff and prepare a seedbed that was more than adequate on these mesic sites. Fires of similar intensity at Miller exposed less mineral soil because of thicker and wetter duff.

Prescribed broadcast fires in the slash at both Miller and Newman had few adverse effects on the soil and little effect on roots or rhizomes more than an inch (25 mm) beneath the surface. In contrast, dozer piling and burning on these sites no doubt would have had significant effects on the soil under the burned piles and would have killed any roots and propagules within it (Vogl and Ryder 1969).

The *Abies lasiocarpa/Clintonia* habitat type (both *Clintonia* and *Menziesia* phases) adequately regenerate if: (1) clearcuts are small (less than approximately 15 acres or 6 hectares), (2) mineral soil is exposed at an adequate number of microsites, say, on 40 percent or less of the toal area, and (3) a seed source is present along two edges. However, clearcuts meeting these criteria on steep slopes of the drier *Xerophyllum* phase still were not adequately regenerated 5 years after burning. High surface temperatures and low soil water contents on these exposed south and west facing slopes indicate the need of shading. Randomly distributed charred debris on broadcast burned sites offers some protection for regenerating conifers. But, on these exposed slopes, the shelterwood system combined with site preparation by broadcast burning would increase the potential for adequate natural regeneration. Broadcast burning under shelterwood would require removal of subalpine fir during the first harvest, or else felling them before burning. They are usually killed by fire and, if standing, frequently will carry fire into the crowns of neighboring trees.

Timing of ripening and dispersal of conifer seed as well as its abundance must be considered when using broadcast fires as a silvicultural tool. Seed crops on upper slopes at Newman were dispersed in early to mid-October. This was 2 weeks to a month later than seed dispersal on nearby lower slopes or valley bottoms at Newman or anywhere throughout the Miller area. Prescribed fires can, therefore, be accomplished on upper slopes through early October before seed is dispersed. Elsewhere the dispersed seed will be destroyed by fires later than about mid-September. Burning after that time may be acceptable during years without satisfactory seed crops, but would be ill advised in a year with a bumper seed crop.

At Newman, the central portion of some clearcuts was seeded by a high proportion of "light-seeded" tree species, such as larch. If a high proportion of "heavy-seeded" species is desired, such as ponderosa pine, the manager should either decrease clearcut size to correspond to seed dispersal limits of desired species or plant the central portion of large clearcuts. Natural dispersal may not provide sufficient seed on dry sites beyond 300 feet (90 m) from the timber edge even in good seed years. For example, the mesic *Thuja/Clintonia* (*Menziesia* phase) habitat type regenerated adequately with half as much seed as fell on *Pseudotsuga/Vaccinium globulare* (*Xerophyllum* phase) habitat type, where regeneration was grossly inadequate.

Germination and seedling survival are better on seedbeds with little or no duff. All species germinated in greater numbers on seedbeds with 0 to one-half inch (0-13 mm) of duff than on those with a thicker duff layer. Engelmann spruce benefited most and Douglas-fir least from exposure of mineral soil. Both germination and seedling survival were more adversely affected by a thick residual duff layer on the steep slopes and drier conditions at Newman than on the more moderate slopes at Miller. Apparently the duff layer must be essentially removed from any microsite on which natural conifer regeneration is expected in the larch/Douglas-fir type. How much of the overall area needs to be bared to mineral soil is a question that can be answered only on a site-by-site basis, taking into account the expected seed crops and all mortality between the time of seed dispersal and satisfactory seedling establishment.

Natural regeneration potential varies significantly by habitat type. Clearcuts on only three of the eight habitat types on the study areas regenerated adequately, with at least 1,000 seedlings per acre (approximately 2,500 per hectare) and with 50 percent of the milacre plots stocked (table 12). Clearcuts on three other types need supplemental planting or seeding to restock them adequately. The regeneration potential of the two Douglas-fir habitat types is marginal at best.

Because most prescribed fires exposed considerable mineral soil on all slopes at both Miller and Newman, direct seeding of larch, spruce, and true firs may be acceptable on all habitat types except those with a poor potential for natural regeneration. Sowing enough seed to assure adequate regeneration on these harsher sites would be impractical because of limited and costly seed supplies. Planting is the only alternative for these sites. Planting was successful for all tested tree species in the *Abies lasiocarpa/Clintonia* habitat type (all phases) at Miller. At Newman, however, planting success for all species other than ponderosa pine varied by habitat type (table 13).

Vegetative Development

Vegetational changes following the treatments at Miller and Newman serve as an ecological baseline, providing a frame of reference so the manager may evaluate and predict the effects of clearcutting and broadcast burning or of wildfire on the plant community. Perhaps the most important general concept for managerial application is a focus of attention beyond the slash reduction aspect of prescribed fire to its effect on the duff layer and the surface mineral soil. It is here that a burning treatment most greatly affects preburn vegetation, seed stored in the soil, and the seedbed for introduced seed.

HERB STAGE OF SUCCESSION

The herb stage usually initiates forest succession. The period of growth for herbs to reach maturity is shorter than that for woody plants. Thus, at the beginning of succession, if herbs, shrubs, and trees all become established in the first year, as they often do, herbs will dominate the initial stage because they grow and develop most rapidly. By definition, herbs annually die back to the ground. With this growth pattern, there often are sudden changes in cover from year to year caused by changing climate conditions. Once initial growth to mature size is complete, further increase in herb cover results from increasing (expanding) populations. Both processes often operate concurrently.

The duration of the herb stage is determined by development rates of predominant species in the next stage. An herb stage 9 or more years old indicates absence or slow development of shrub or tree species. Any particular stage of succession seldom shuts itself down, rather it is replaced by development of another, more dominant, life form. Therefore, those areas with short herb stages had rapidly developing shrub components.

Table 12.—Expected natural regeneration potential by habitat type

Habitat type	Seedling density	Stocking	Natural regeneration potential
	Trees/acre	*Percent*	
Abies lasiocarpa/Clintonia (*Menziesia* phase)	2,916	76	Good
Thuja/Clintonia (*Menziesia* phase)	2,076	70	Good
Abies lasiocarpa/Clintonia (*Clintonia* phase)	3,160	60	Good
Abies grandis/Clintonia	960	43	Fair
Abies lasiocarpa/Clintonia (*Xerophyllum* phase)	1,796	32	Fair
Abies grandis/Xerophyllum	331	18	Poor
Pseudotsuga/Physocarpus	438	12	Poor
Pseudotsuga/Vaccinium globulare (*Xerophyllum* phase)	108	6	Poor

Table 13.—Expected survival for planted conifers by habitat type on Newman Ridge

Habitat type	Expected species survival		
	Highest	Moderate	Lowest
Abies grandis/Clintonia	—	Lodgepole pine Douglas-fir Western larch Grand fir	—
Abies grandis/Xerophyllum	Ponderosa pine	Douglas-fir Western larch Lodgepole pine Grand fir	—
Pseudotsuga/Physocarpus	Ponderosa pine	—	Western larch Douglas-fir Lodgepole pine
Pseudotsuga/Vaccinium globulare	Ponderosa pine	Douglas-fir Western larch Lodgepole pine	—
Thuja/Clintonia	Western larch Douglas-fir Lodgepole pine Grand fir	—	—

This pattern may result from either a high survival of preburn resident shrubs or the presence of rapidly growing pioneer shrubs. Most rapid shrub development usually results from a combination of these two processes, as on several units at Newman.

FIRE EFFECTIVENESS

The influence of fire on undergrowth and juvenile overstory plants is centered at the mineral soil-duff surface. The more heat applied here, the greater is mortality of resident plant species, and the greater is the opportunity for site occupancy by invading pioneers. Conversely, the less heat applied to this point, the higher the survival of resident plants and the less suited is the site for pioneer species. The key to changing abundance and composition of vegetation lies in controlling fire intensity, or more specifically, in controlling the amount of heat applied to the mineral soil-duff surface. In this study, those units with the driest lower duff at the time of burning produced postburn site conditions most favorable to pioneer species.

Many very desirable timber species and shrubs that supply excellent wildlife habitat are pioneers. On Miller and Newman these include western larch, lodgepole pine, snowbrush ceanothus, and Scouler willow. Of the 14 units sampled at Miller, those burned by wildfire had the greatest development of pioneer shrubs as well as an abundance of tree seedlings. At Newman a similar response was noted where hot prescribed fires emulated the Miller wildfire; however, the pioneer tree component here was not as abundantly represented. Clearcutting at Newman removed both the on-site seed source and the temporal shade for ameliorating the environment of tree seedlings.

Unit S-13 at Miller provides a classic example of how the mesic conifer forest in the Northern Rocky Mountains responds to disturbance by wildfire. All major components of the seral vegetation are developing on this unit in an environment that must closely approximate that under which the former forest stand evolved. The composition of the plant community resulting rom this intense fire, during which most of the duff was burned, when compared with that resulting from a less effective fire on S-1 at Miller, s evidence that both silvicultural and big-game habitat values can be enhanced by effective burning.

Effective fires remove or markedly reduce resident plant species and make the site more favorable for immigrant or pioneer species. Thus the potential for manipulating changes in vegetation is greatest following intense and effective fires. Conversely, low effective burning treatment somewhat reduces resident species, but not enough to prevent their rapid recovery and return to their earlier level of competition. For example, on many sites at Miller or Newman, if snowbrush ceanothus is the favored species, an intense and effective fire should be prescribed; whereas, if blue huckleberry is the favored species, a less effective fire would be in order.

Small Mammals

Seed-eating rodents are common, making up 70 to 98 percent of the small mammal community in the forest environment. In some years these rodents are much more abundant than in others. Deer mice, especially, follow a consistent pattern of increasing markedly during the year following a heavy conifer seed crop.

Even an intense, deep-burning fire will not eliminate rodents, but it does sharply reduce the diversity of small mammal species, essentially leaving deer mice as survivors. Deer mice appear to survive even an intense fire in good numbers; then their populations rapidly increase through reproduction and through invasion of the burned area. A fire, in which understory vegetation is mainly altered in degrees rather than kind, can sharply reduce small mammal populations for a year following treatment. By then exceptionally good habitat for rodents has developed and sustained high populations of several species are maintained on the lightly burned site for 4 or more years. Such a fire may temporarily offer the least hazard to tree seeds and seedlings from rodents because of the buffering effect of other abundant food combined with relatively low populations of seed-eating rodents.

Rodent populations generally are favored by clearcutting and broadcast burning. These increased populations, being made up of primarily conifer seed-eaters, can measurably reduce tree regeneration from seed. Especially on clean burns, direct seeding should not be attempted without taking rodent control measures because of high deer mouse populations for at least 4 postburn years. By then planting may be the only reasonable alternative.

Small mammals, like many familiar wildlife species, reach their annual maximum numbers at the end of each growing season, when food and cover are most abundant. They are least numerous in the spring, after the winter stress period. Therefore, direct seeding of conifers is best done in the spring, especially if there has been a heavy seed crop the previous year, prior to annual recruitment in the rodent population. Thus, seeds may germinate and seedlings develop before the rodent population peaks.

Soils and Watershed

The soils and watershed data were taken from undisturbed forest and from sites that had been clearcut and broadcast burned. Some soils data also came from the Miller wildfire area. These are the treatments to which these results may be applied. The runoff and erosion data definitely do not apply to roads, trails, and other drastically disturbed sites, even though these sites usually undergo the most accelerated erosion and produce most of the sediment associated with logging operations.

Burning of logging debris in this northern coniferous forest, if broadcast over the clearcut area, should not induce sufficient water repellency into these medium- to fine-textured soils to be of any concern to land managers. Nor should the small reduction in organic matter in the surface mineral soil be cause for worry. Changes in the surface organic horizon, however, particularly its complete consumption by intense fires, may be of significance. This surface organic layer protects the soil from direct raindrop impact. Loss of this organic layer on steep slopes, such as at Newman, may result in severe erosion if intense summer storms are received.

Clearcutting and broadcast burning effected some measurable changes in soil chemistry and nutrient availability. Nutrient cycling was interrupted, the soil environment was altered, and a layer of debris and ash was deposited on the surface. Burning volatilized about a third of the nitrogen in the surface organic horizon. Leaching and erosion of the ash-duff layer during the next 2 years markedly reduced the nutrient content of this horizon. At least part of this loss can be accounted for by an increased available nutrient content in the underlying mineral soil. Mineral soil pH also increased. These relatively fine-textured soils probably trapped within the rooting zone most of the nutrients released by cutting and burning. Nitrogen lost through volatilization is great, but most of this is part of the total nitrogen supply. Total nitrogen is no measure of nitrogen actually available for plant growth. Available nitrogen supplies were not assessed.

Rapid recovery of vegetation on these sites has reestablished nutrient cycling and has again protected the soil surface. None of the nutrient changes measured should adversely alter site quality.

The relatively small amounts of soil erosion measured on these plots should be comforting to managers contemplating similar treatment on similar soils and slopes. The maximum amount of eroded material produced from each acre at Miller during the first year after treatment was only a few hundred pounds. This amount of sediment easily can be kept from streams with the use of undisturbed buffer strips. An example of more severe erosion from summer storms occurred on the steeper slopes at Newman with the chance occurrence of an intense storm during the first summer. However, even here, erosion from the logged-burned plots cannot be considered severe even by conservative agricultural standards.

Impairment of watershed protection and attendant increases in runoff and erosion are quite similar on both areas. With the exception of southerly aspects, the impact is acceptable. Southerly aspects are driest, they were impacted with the most intense burns, and they exhibited the most adverse effects to soil and vegetative characteristics as a result of treatment. Most importantly, these south slopes recovered least during the 7 years following burning.

With reasonable precautions, site quality and aquatic habitat will not be adversely impacted from clearcutting and broadcast burning on these or similar sites. The precautions are those that apply anywhere in mountainous terrain—to minimize mineral soil exposure and disturbance, especially through construction of roads, skid trails, and firebreaks. A further recommendation would be to minimize disturbance on south-facing slopes. These recovered slowly and were thus exposed for an unacceptably long period to overland flow and erosion. Perhaps a shelterwood system would be more appropriate on south slopes.

Interactions

Quantitative data available from this research deal almost exclusively with effects of clearcutting and fire on discrete resources or disciplines. It is well known, however, that these entities interact. Research design, unfortunately, does not permit a quantitative analysis of second-level interactions that followed clearcutting and fire. Therefore the remainder of this discussion is qualitative; it describes some observations made on the Miller and Newman areas during the course of this study and their possible implications.

SMOKE MANAGEMENT AND THE SOIL AND WATER RESOURCE

Some plant nutrients are volatilized in fires and some are carried away as particulate matter in the smoke. Those lost through volatilization are, for all intents and purposes, permanently added to the atmosphere. But those carried aloft as 30 pounds of particulate matter per ton of fuel consumed are returned to the earth's surface. This return occurs as fallout of flyash for several miles downwind from the fire, as physical trapping of smoke particulates in vegetation downwind from the fire (especially applicable to low-intensity fires without a convection column), and as precipitation, with the fine particulates being nuclei for the formation of water droplets.

The concentration of nutrients in precipitation falling through smoke plumes from forest fires may be 20 to 70 times greater than normal (Clayton 1976). DeByle and Packer (1972) noted an unexplained increase in the nutrient content of overland flow from control plots in the forested areas at Miller in 1967, when the greatest acreage was burned. Trapping of dry airborne ash by the uncut forest, and return of particulate matter in precipitation may have accounted for this increased nutrient content. This transfer of plant nutrients in forest fire smoke is statistically significant but apparently of little ecological importance (Clayton 1976). It should be noted, though, that the nutrients lost in smoke particulates from burned sites become nutrient additions at downwind locations. The direction, distance, and dilution of this downwind aerial fertilization can be partially controlled from prescribed fires.

SILVICULTURE AND VEGETATIVE DEVELOPMENT

Growth of vegetation after clearcutting and broadcast slash burning and the successional changes in this vegetation affect establishment and growth of conifer seedlings. As pointed out earlier, intense fires reduced competing vegetation to a minimum, set back plant succession furthest, and provided the most exposure of mineral soil as seedbed. But protection and shading of the site are also reduced to a minimum by intense fires. Most of these sites are quickly occupied with herbaceous vegetation, particularly fireweed, and shading for the newly established conifer seedlings is provided. The shade of living vegetation may favorably alter the microclimate for conifer seedlings; but as this vegetation develops, it also competes with relatively slow-growing conifer seedlings for light, nutrients, and water. Data are not available from Miller or Newman at this stage of vegetational development to assess the degree of competition between seedlings and other vegetation. Nor are there data available to quantify the effects of shade from this vegetation on the survival and growth of conifer seedlings. When both pioneer shrubs and trees become established in the first year, as on Miller S-12 and S-13, the effects of shrubs on tree seedlings would be less than if there is a delay in tree establishment.

Low-intensity fires that do not remove the duff layer not only do not provide an adequate seedbed for conifers, but those seedlings that develop on these sites grow more slowly than on intensely burned areas. This, in part, may be due to less competition from other vegetation on intensely burned sites. On sites with low-intensity and less effective fires, new conifer seedlings must compete with already established vegetation.

SILVICULTURE AND SMALL MAMMALS

The interactions between seed-eating rodents and seed and seedling survival of conifers are explained under Small Mammal Populations in the Results and Discussion sections. An additional but speculative point deserves attention. A fire that kills all aboveground vegetation and bares the mineral soil, initially reduces the rodent population but, shortly afterward, provides an ideal habitat for a large increase in deer mice, primarily seed-eaters. The same physical conditions provide the best conifer seedbed. In contrast, a less effective fire does not deplete the rodent population nor its food supply as much, does not cause as marked an increase in seed-eating rodent numbers, and, as a result, there should be less impact on conifer seed and seedlings by these rodents. It would appear that more conifer seeds would survive on these burns to allow stocking of those few microsites that were properly prepared, namely burned to mineral soil. If true, this is evidence for a natural balance having evolved between fire intensity, rodent populations, and conifer seedling establishment.

SILVICULTURE AND THE SOIL AND WATER RESOURCE

As stated earlier, conifer seedlings growing on burned areas were more vigorous than those on unburned sites. This increased vigor may be due to less competition from other vegetation (already speculated) or be due to a more favorable chemical and physical environment. The ash, as shown in the soils results, adds a small amount of available plant nutrients to the surface mineral soil. Also, the blackened and exposed surface results in an altered microclimate, both above and within the soil, that may be more favorable to conifer seedling growth.

Drought was the leading cause of seedling death on south slopes and the second leading cause on all others. Careful management may reduce this mortality. In part the soil moisture regimen can be influenced by management. Shade from dead vegetation not only will prevent lethal temperatures at the soil-air interface, but also will reduce evaporation from the surface soil, the critical layer for newly established seedlings. However, live vegetation competing with the conifer seedlings usually transpires more water than its shade conserves. When extrapolating these results to other locations, it must be kept in mind that fine-textured soils, such as the clays and loams at Miller and Newman, contain a greater amount of available water for plant growth than coarse-textured soils. For this reason, a south-facing slope with coarse sandy soil that has been denuded of all vegetation, both live and dead, will be an especially harsh environment for conifer seedling survival during dry summers, such as that experienced in 1967.

The silviculturist who wants bare soil exposed for the best conifer seedbed and the watershed manager who desires a layer of vegetation and duff to protect the mineral soil from raindrop impact and overland flow seem to have conflicting goals. These opposing objectives are more apparent than real. The bare soil openings necessary for satisfactory forest regeneration need not be large nor extensive enough to cause undue accelerated erosion. Through the use of broadcast prescribed burning, it is possible to reduce plant competition, expose sufficient mineral soil microsites for tree seedling establishment, and still maintain satisfactory mineral soil cover to control erosion from all but the most intense storms. The silviculturist and watershed manager are really in agreement on what is needed—partial exposure of mineral soil to permit sufficient but not too much natural forest regeneration, and sufficient protection of the site with dead vegetation. This agreement is particularly obvious in the recommendations given for south exposure at both Miller and Newman, where a shelterwood system is probably best from both points of view.

SILVICULTURE AND ESTHETICS AND WILDLIFE

This study and others have shown that natural regeneration of most conifer species on small clearcuts is more uniform and abundant than on large clearcuts. Seed dispersal of most conifers is not sufficient to adequately regenerate sites more than 100 yards (approximately 100 m) from the uncut forest. Again, good silviculture and other forest uses are in agreement. Small clearcuts are less of an esthetic impact than large ones. Small clearcuts also offer the maximum edge and greatest diversity of habitats for wildlife. Wild ungulates will use the entire area of small clearcuts for browsing as opposed to primarily the periphery of large openings.

If carefully done, broadcast burning will bare the desired amount of mineral soil for forest regeneration. Frequently, too much is bared with dozer piling of slash. Also, broadcast burning leaves a relatively uniform distribution of shade from logs and dead vegetation. Dozer piling of slash removes this shade. Broadcast burning has much less esthetic impact than other debris disposal techniques. Within a few years after treatment the broadcast burned site, with its uniform distribution of coarse debris, appears much more natural than the remains of piled or windrowed debris from other conventional slash disposal methods.

In recent years there has been increased emphasis on maintenance of avian habitats in the managed forest, especially habitat for cavity nesters and raptors. This was not a part of the Miller-Newman research. Hence, all trees were felled on all of the clearcuts. However, there was no pressing reason that this had to be done. Some trees could have remained. To maintain cavity nesting and feeding sites as well as raptor perches, as many large cull trees and snags as possible should be left standing (McClelland and others 1979). Ideally, culls ought to be killed in the prescribed fire to prevent their competing with the next crop of trees, to prevent their providing perhaps genetically inferior seed, and to control any insects or diseases present in them. To insure these culls are girdled with sufficient heat, slash fuel should be concentrated about their bases. Because they may "crown out," these trees must be away from the periphery of clearcuts, so control of the prescribed fire would not be jeopardized. These dead trees may benefit the developing forest under them—by providing shade, by providing nesting habitat for insectivorous birds, and by providing perches for raptors that prey on seed-eating rodents. On the other hand, on sites where lightning strikes are common, these snags may create an unacceptable fire hazard that could threaten the surrounding young forest.

VEGETATIVE DEVELOPMENT AND SMALL MAMMAL POPULATIONS

This research has shown that size and the diversity of rodent populations are related to cover, size, and species diversity of vegetation. At Newman this was especially evident on the contrasting lightly burned north and intensely burned south slopes. Possible influences of vegetation on these mammal populations have been discussed. The converse, the effect of small mammals on the developing vegetation, remains unknown. With the exception of conifer seedling establishment and development, there has been no attempt in this research to quantify this effect. For example, we do not know what role rodents play in distributing seeds of shrubs, or in establishing forbs or shrubs in this environment.

VEGETATIVE DEVELOPMENT AND THE SOIL AND WATER RESOURCE

Especially where fireweed was an important component of the postburn vegetation, herbaceous growth flourished during the first 2 or 3 postburn years. Was this flush, which often seemed to decline without cause, due to fertilization of these sites by ash? Was it due to microclimate alteration? Or was it due to the ecophysiology of the plant species involved? Perhaps it is a combination of all three. Fertilization was present, but seemed trivial. Both the above- and belowground microclimate was altered by clearcutting and fire; and it is well known that the principal species, fireweed, dominates many northern coniferous sites after burning and, therefore, must be especially adapted to these conditions. As is so frequently the case in research—one question is answered (fireweed increases markedly, then for no apparent reason declines) only to raise a more fundamental question—why?

Plant cover data were taken on control plots and on clearcut and burned plots for several years to help explain the amount of runoff and erosion experienced. These data were gathered with a much different technique (a point analyzer that resulted in precise measurements of cover at or very near the soil surface on small transects) than the cover measurements taken for assessing vegetative development (estimates of cover on larger transects from a reference point farther above the ground). Also, the units and transects used for quantifying vegetative development were not the same as the units and locations of the runoff plots. Despite these differences, the data from runoff plots and vegetative development transects that have been subjected to similar treatments and conditions show similar trends. Differences noted often are due to location; for example, none of the runoff plots were situated where dense growth of ceanothus occurred after burning, whereas some of the vegetation development transects were in dense ceanothus patches.

The usual cycling of nutrients in the northern coniferous forest is interrupted by the treatments applied at Miller and Newman. During the first postburn year uptake of nutrients by plants is minimal. How soon the cycling of nutrients into developing vegetation, and their return each year as litter, reaches a level similar to that of the preharvest forest was not determined. Perhaps in this forest type this is reached when deeply rooted shrubs and young trees again fully occupy the site. This on the average probably would be 10 to 20 years after harvesting and broadcast burning at Miller and Newman.

Soil microclimate, soil pH, and the amount and chemical nature of available nitrogen are all affected by the amount and the species composition of vegetation developing after treatment. Available nitrates should be more abundant and soil pH higher in the early stages of herbaceous and pioneer shrub cover than after the sites again become dominated by coniferous forest. Microclimate is markedly altered by clearcutting and burning, then begins a gradual return to pretreatment conditions as vegetation and the organic soil horizon develop. Because none of these effects have been actually measured in the Miller-Newman research, we can only speculate on the magnitude and direction of these nutrient and microclimate changes.

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APPENDIX A

COMMON AND SCIENTIFIC NAMES OF SPECIES

(Little 1953; Hitchcock and Cronquist 1973; Jones and others 1975; Garrison and others 1976; and Pfister and others 1977.)

Animals

Clethrionomys gapperi	southern red-backed vole
Eutamias ruficaudus	red-tailed chipmunk
Glaucomys sabrinus	northern flying squirrel
Lepus americanus	snowshoe hare
Microtus longicaudus	long-tailed vole
Mustela erminea	ermine
Neotoma cinerea	bushy-tailed woodrat
Peromyscus maniculatus	deer mouse
Sorex vagrans	vagrant shrew
Tamiasciurus hudsonicus	red squirrel

Plants

Trees

Abies grandis (Dougl.) Lindl.	grand fir
Abies lasiocarpa (Hook.) Nutt.	subalpine fir
Larix occidentalis Nutt.	western larch
Picea engelmannii Parry	Engelmann spruce
Pinus contorta Dougl.	lodgepole pine
Pinus monticola Dougl.	western white pine
Pinus ponderosa Laws.	ponderosa pine
Pseudotsuga menziesii (Mirb.) Franco	Douglas-fir
Thuja plicata Donn	western redcedar

Shrubs

Acer glabrum Torr.	Rocky Mountain maple
Ceanothus velutinus Dougl.	snowbrush ceanothus
Lennaea borealis L.	longtube twinflower
Menziesia ferruginea Smith	rusty menziesia
Physocarpus malvaceus (Greene) Kuntze	mallow ninebark
Rubus parviflorus Nutt.	western thimbleberry
Salix scouleriana Barratt	Scouler willow
Spiraea betulifolia Pall.	birchleaf spirea
Taxus brevifolia Nutt.	Pacific yew
Vaccinium globulare Rydb.	blue huckleberry

Herbs and Grasses

Arnica latifolia Bong.	broadleaf arnica
Calamagrostis rubescens Buckl.	pinegrass
Carex concinnoides Mack.	northwestern sedge
Clintonia uniflora (Schult.) Kunth	queencup beadlily
Coptis occidentalis (Nutt.) T. & G.	goldthread
Epilobium angustifolium L.	fireweed
Epilobium paniculatum Nutt.	autumn willowweed
Xerophyllum tenax (Pursh) Nutt.	common beargrass

APPENDIX B

PREDICTING MINERAL SOIL EXPOSURE WITH USE OF THE DUFF REDUCTION TABLE

The percentage of the area burned bare to mineral soil in western larch/Douglas-fir forests can be predicted by using the following procedure:

1. Take 100 or more duff depth measurements before burning, with the sample points scattered throughout the planned burn unit.
2. Decide the percentage of the area you desire to have burned bare to mineral soil. For an example, assume 60 percent bare is chosen.
3. List preburn duff depths taken. For example:

Duff depths (inches)

4
3
2
1
0
6
5
3
4
3

In this case there are only 10 measurements for the sake of keeping the example simple, so n=10. To have 60 percent of the area bare to mineral soil, six of these representative points must be reduced to zero depth.

4. Since duff tends to be consumed in a more or less uniform layer, examine the list to see how thick a layer must be burned off to bare 60 percent of the points. Proceed as follows:

1 point is zero, or 10 percent of the area sampled

2 points are 1 inch or less, or 20 percent of the area sampled

3 points are 2 inches or less, or 30 percent of the area sampled

6 points are 3 inches or less, or 60 percent of the area sampled.

Therefore a layer 3 inches thick must be burned away. Of course, some points do not have 3 inches of duff, but if a fire is prescribed that will consume 3 inches of duff, those with less will be bared along with those that have 3 inches.

5. Compute the percentage of loss for each point if 3 inches are removed, and average the result. If the preburn depth is less than 3, award that sample point 100 percent. With use of the example, proceed as follows:

$3 \div 4 = 0.75 \times 100 = 75\%$
$3 \div 3 = 1.0 \times 100 = 100\%$
2 100%
1 100%
0 100%
$3 \div 6 = 0.5 \times 100 = 50\%$
$3 \div 5 = 0.6 \times 100 = 60\%$
$3 \div 3 = 1.0 \times 100 = 100\%$
$3 \div 4 = 0.75 \times 100 = 75\%$
$3 \div 3 = 1.0 \times 100 = 100\%$

$$\text{Total} = 860$$
$$\text{Average} = \text{Total}/n = \frac{860}{10} = 86\%$$

Therefore, an 86 percent reduction in duff depth is needed to achieve exposure of mineral soil on 60 percent of the area.

6. Refer to table 2, reproduced here for convenience, to find the prescribed conditions for achieving 86 percent duff depth reduction. A measure of fuel loading on the area is necessary to determine if there are sufficient fuels to create a fire hot enough to consume the desired amount of duff. As stated earlier, expected fuel consumption can be predicted by multiplying the loading of small diameter fuels by 0.78. Then enter table 2 in the fuel consumption column closest to the result. For the example, assume a preburn weight of small fuels to be 20 tons per acre. Twenty x 0.78 = 15.6, so enter the table under the column headed 15 tons per acre. At this loading, it is possible to remove 90 percent of the duff if it is at 5 percent water content. Since the desired duff depth reduction is 86 percent, it is necessary to burn at a much higher duff water content, somewhere between 55 and 60 percent. Note, as discussed earlier, that the burning should be done when the water content of small fuels (not duff) is within the range of 10 and 17 percent.

Table 2.—Percentage of duff depth consumed predicted from duff water content and fuel consumption (from page 18)

Water content of lower half of duff layer	Tons per acre (t/ha) of small (<4 inch or <10 cm diam.) fuels consumed			
	5(11)	10(22)	15(34)	20(45)
Percent	---*Percentage of duff depth reduction*----			
5	60	78	90	100
10	59	78	90	100
15	57	78	90	100
20	55	77	90	100
25	53	77	90	100
30	51	76	90	100
35	48	74	89	100
40	46	73	89	100
45	43	70	89	100
50	41	68	88	100
55	39	65	87	100
60	36	61	85	100
65	34	58	83	99
70	32	54	80	99
75	30	49	77	98
80	28	45	73	97
85	26	41	69	96
90	24	36	64	95
95	22	32	59	94
100	21	29	53	92
105	19	25	47	89
110	18	22	41	86
115	17	19	36	82
120	15	17	31	78
125	14	15	27	73
130	13	14	23	68
135	12	13	21	62
140	11	12	19	56
145	11	11	17	50
150	10	11	16	44
155	9	11	16	38
160	9	10	16	34
165	8	10	15	30
170	8	10	15	27
175	7	10	15	24
180	7	10	15	23
185	6	10	15	22
190	6	10	15	21
195	6	10	15	21
200	6	10	15	21
205	5	10	15	21
210	5	10	15	21
215	5	10	15	21
220	5	10	15	21

APPENDIX C

SELECTED ANNOTATED BIBLIOGRAPHY: MILLER CREEK-NEWMAN RIDGE RESEARCH

Adams, D. F., and R. K. Koppe.

1969. Instrumenting light aircraft for air pollution research. J. Air. Pollut. Control Assoc. 19(6):410-415.

The airborne instrumentation package described measures and records up to 27 pollutant and flight variables. Real-time analysis instrumentation includes nondispersive infra-red analyzers for CO_2, CO, and hydrocarbons, conductivity and coulometric analyzers for sulfur dioxide and sulfur-containing gases, and a Charlson-Ahlquist visual range nephelometer. A Battelle "bulk sampler" is used to collect particulates. Air speed, altitude, rate of climb, magnetic heading, temperature, and relative humidity are continuously measured. All variables are recorded on magnetic tape. Tape data are reduced directly by IBM 360 computer to a digital printout or from tape to an X-Y analog plot.

Adams, Donald F., Robert K. Koppe, and Elmer Robinson.

1976. Air and surface measurements of constituents of prescribed forest slash smoke. *In* Proc. Int. Symp: Air Quality and Smoke from Urban and Forest Fires [Fort Collins, Colo. Oct. 1973]. p. 105-147. Natl. Acad. Sci., Washington. D.C.

Data from a ground-level network of air sampling stations, measurements of smoke plumes from the aircraft, and results from laboratory studies on burning tables are presented and discussed. Airborne particulate concentration near the ground surface was significantly raised at downwind locations on fire days. Dispersion of smoke at higher altitudes was measured through sampling of particulates and CO_2 in plumes from several fires with instruments aboard the aircraft.

Beaufait, William R.

1968. Scheduling prescribed fires to alter smoke production and dispersion. *In* Prescribed burning and management of air quality, Southwest Interagency Fire Counc. Proc. 1968:33-42.

The Northern Region-Intermountain Station cooperative study of the use of fire in silviculture is described. Instrumentation for data collection, especially that associated with Washington State University's air pollution research is discussed. Convection columns rose to a higher altitude and smoke plumes were more greatly dispersed from Miller fires when fuels were relatively dry and lapse rate was favorable than under the reverse conditions. To minimize smoke effects, fires should be scheduled when fuels are dry enough to create a strong convection column. Meteorological and fuel conditions required for adequate smoke dispersion can be made to correspond with those that achieve the objectives of land management through prescribing burning.

Beaufait, William R.

1971. Fire and smoke in Montana forests. *In* Forest land use and the environment. 23 p. Mont. For. and Range Exp. Stn., Sch. For., Univ. Mont., Missoula.

Fuel accumulates in most northern forests. Fire, playing its natural role, periodically removes this accumulation. The particulates in the smoke from these fires are an air pollutant of concern. Fires are inevitable; but their timing, severity, and dispersion of smoke from them are partially under man's control. The timing, duration, and severity of prescribed fires may be chosen and controlled so as to manage the direction and altitude of smoke plumes and thus avoid air pollution of downwind populated valleys. Nature's fuel management with wildfires does not permit this control.

Beaufait, William R., and Owen P. Cramer.

1969. Prescribed fire smoke dispersion-principles. USDA For. Serv., North. Reg., In-Serv. Rep., 12 p. Missoula, Mont. (Rev. Jan. 1972).

An illustrated presentation of the principles that must be considered in developing prescribed burning guidelines and in successfully conducting prescribed fires that result in efficient smoke dispersal.

Beaufait, William R., and William C. Fischer.

1969. Identifying weather suitable for prescribed burning. USDA For. Serv. Res. Note INT-94, 7 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Fire managers require continuous (24-hour) records of temperature, relative humidity, and windspeed to use fire efficiently and effectively. When carefully calibrated and interpreted, modified hygrothermographs provide the minimum instrumentation needed to obtain these records. An actual case of record interpretation and use is included.

Beaufait, William R., Charles E. Hardy, and William C. Fischer.

1977. Broadcast burning in larch-fir clearcuts: the Miller Creek-Newman Ridge study. USDA For. Serv. Res. Pap. INT-175, rev., 53 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Seventy-three clearcuts in western larch/Douglas-fir forests of western Montana were broadcast burned over a wide range of environmental conditions for the purpose of quantifying fire characteristics and burn accomplishment. The water content of the upper duff layer, and the National Fire-Danger Rating System Buildup Index (1964) were important predictors of both the heat pulse to the site and the amount of duff removed by the fire. The same two variables, along with the preburn weight of 1- to 10-cm diameter fuels, were the best predictors of the amount of fuel consumed by the fire.

Beaufait, William R., Michael A. Marsden, and Rodney A. Norum.

1974. Inventory of slash fuels using 3P subsampling. USDA For. Serv. Gen. Tech. Rep. INT-13, 17 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

The large-scale study of prescribed broadcast burning in western Montana required development of a system to inventory clearcut logging slash fuels before and after fire treatment. The system is best suited for inventorying material that tends to be oriented parallel to the ground. The inventory system uses line intercept counts to compute volume, weight, and surface area of fuels. 3P subsampling is used to inventory twigs (0-1 cm diameter). Data reduction was accomplished with specially written computer programs. When used with proper and sufficient subsampling for collateral data, the system is well suited for the inventory of slash fuels in many forest types.

Brown, James K.

1970. Vertical distribution of fuel in spruce-fir logging slash. USDA For. Serv. Res. Pap. INT-81, 9 p. Intermt. for. and Range Exp. Stn., Ogden, Utah.

About 70 percent of the volume and surface area of spruce-fir logging slash lies below the middepth of the slash. Material 0 to 1 centimeter in diameter was distributed vertically in the same proportions as all other material. Old slash in the first 20 centimeters above the ground contained a greater proportion of large material than new slash. Quantity of slash averaged 26.5 kg/m (118 tons/acre) dry weight with 0.57 kg/m composed of material 0 to 1 centimeter in diameter. Bulk density of slash decreased vertically and averaged 0.030 g/cm^3 for new slash and 0.053 for old slash. Needle mats suspended in the slash occurred with a 40 percent frequency.

DeByle, Norbert V.

1973. Broadcast burning of logging residues and the water repellency of soils. Northwest Sci. 47(2):77-87.

Pertinent literature is reviewed and summarized. Water repellency of both organic and mineral soil horizons under larch and Douglas-fir were evaluated. The dry, decomposing litter was very water repellent. But probably because the underlying soil typically is moist when a prescribed fire is conducted, burning the slash did not alter the wettability of these medium- to fine-textured soils, even when the duff layer was almost entirely consumed. Burning of logging debris in the northern coniferous forest, if broadcast over the clearcut area, should not induce sufficient water repellency into medium- to fine-textured soils to be of concern. In contrast, the high temperatures reached at the soil surface beneath burned piles of slash or an intense wildfire on a dry soil mantle may induce water repellency, especially in coarse-textured soils.

DeByle, Norbert V., and Paul E. Packer.

1972. Plant nutrient and soil losses in overland flow from burned forest clearcuts. *In* Watersheds in transition. p. 296-307. Am. Water Resour. Assoc. Symp. Proc.

The results of physical and chemical analyses of the overland flow and sediment from 12 runoff plots at Miller and 12 at Newman are presented in detail. Logging and burning temporarily impaired watershed protection and increased overland flow and erosion, especially on the steep slopes at Newman. However, vegetal recovery returned conditions to near prelogging status within 4 years. There was an increase in plant nutrient losses in both the sediment and in the overland flow during the denuded period; but it represented only a small fraction of the nutrient capital.

DeByle, Norbert V.

1976. Fire, logging, and debris disposal effects on soil and water in northern coniferous forests. Proc. XVI IUFRO World Congr., Oslo, Norway, 1976:201-212.

The author explains why under some conditions clearcutting or fire has severe impacts on the environment and why under other conditions impacts are minimal or not even detectable. The variables of soils, geology, topography, climate, and forest type are considered.

DeByle, Norbert V.
1976. Soil fertility as affected by broadcast burning following clearcutting in Northern Rocky Mountain larch/fir forests. Fire and Land Manage. Symp. [Missoula, Mont., Oct. 8-10, 1974]. *In* Proc. Tall Timbers Fire Ecol. Conf. 14:447-464.

Plant nutrient content and associated soil parameters were determined under 35 monitored burns of broadcast logging debris at Miller Creek n western Montana. The duff or ash-duff mixture and four increments to a 30 cm depth into mineral soil were sampled before, immediately after, and or up to 2 years after burning. Data are reported or pH, cation exchange capacity, organic matter, nitrogen, phosphorus, potassium, sodium, calcium, and magnesium. Burning volatilized a third of the nitrogen in the organic surface horizon. Leaching and erosion of the surface ash-duff layer during the next 2 years markedly reduced its nutrient content. The pH and the content of some available nutrients in the underlying mineral soil ncreased. Most nutrients leached from the surace probably were held beneath in the relatively ine textured mineral soils.

Fiedler, Carl E.
1974. Atmospheric conditions surrounding a seedfall in western Montana. M.S. thesis. Sch. For., Univ. Mont., Missoula. 46 p.

Wind movement over two clearcuts of opposng aspect and the intervening ridge was studied. Continuous data on windspeed and direction were aken at three locations. A series of tethered weather balloons along the clearcut edges provided supplemental data. Movement of these balloons with changing wind patterns was recorded with time lapse photography. Dispersal of smoke from smoke grenades was also photographed. Wind behavior on opposite aspects and he ridgetop and likely effects on seed disseminaion are discussed.

Fischer, William C., William R. Beaufait, and Rodney A. Norum.
1969. The hygrothermoaerograph—construction and fire management application. USDA For. Serv. Res. Note INT-87, 8 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Conventional hygrothermographs can be modified to record windspeed along with temperaure and relative humidity. The fire-weather record resulting from the modification has applicaion in prescribed fire planning, fire-danger rating, ire-weather forecasting, fire-behavior analysis, and fire-weather climatology.

Flaherty, David C.
1967. Better burns...and better air? Quest, Dec. 1967:16-21. Wash. State Univ., Pullman.

This article, written in popular style, summarizes the objectives of the Miller Creek study and highlights the air pollution research of Washington State University.

Flaherty, David C.
1972. Are we objective about forest fires? Am. For. 78(9):12-15, 58-59.

This popular article concerning fire's role in the environment is based on an interview with W. R. Beaufait. Beaufait explains why fire is a natural component of the Northern Rocky Mountain forests. He describes how the Northern Region-Intermountain Station cooperative studies contribute to a better understanding of the use of fire in silviculture.

Koppe, Robert K., and Donald F. Adams.
1969. Dispersion of prescribed fire smoke. Pap. 69-AP-36, 21 p. Wash. State Univ., Pullman.

Results of airborne sampling for aerosols and carbon dioxide in the smoke plumes of two typical prescribed fires at Miller are described. The major portion of one plume was transported downwind at 3950 m altitude at a rate between 15 and 21 m/sec, near that of the calculated windspeed at that elevation. There was excellent correlation between smoke particles and carbon dioxide concentration for 25 km downwind from prescribed fires, where carbon dioxide level in the diffusing plume was approximately 10 percent above background. From 25 to 55 km downwind the carbon dioxide concentration in the plume and the background were comparable, although the boundary of the plume was clearly discerned by the sampling instruments. Aerial intercepts of the edge of the convection column during the initial buildup phase of the fire revealed carbon dioxide concentrations up to 500 parts per million.

Malte, P.C.
1975. Pollutant production from forest slash burns. Wash. State Univ., College Eng. Bull. 339, 32 p.

The percentage of slash fuel converted to smoke is presented for three Newman fires. Concentrations of particulate matter and CO_2 were determined with airborne sampling devices. Fuel inventories, moisture content data, elemental analyses for C/H/N, and burning table results were also utilized. Relatively dry forest slash

composed primarily of Douglas-fir and larch, with moisture contents of approximately 5 percent for needles, 10 percent for twigs, and 30 percent for the forest-floor duff, gave mass ratios of pollutant to burned material (including moisture) of approximately 1.4 for CO_2, 0.016 for particulate, 0.12 for CO, and 0.008 for NO_2. For one fire, the particulate/CO_2 ratio increased markedly as the fire grew during the first hour. Another fire plume gave a steady, apparently maximum, particulate/CO_2 ratio of 0.014 at the 1-hour point.

Norum, Rodney A.
1970. Probable smoke column heights from slash fires. M.S. thesis. Sch. For., Univ. Mont., Missoula, 65 p.

This is a more detailed report of the material presented in the following cited Research Paper INT-157.

Norum, Rodney A.
1974. Smoke column height related to fire intensity. USDA For. Serv. Res. Pap. INT-157, 7 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

The ultimate height of slash-fire smoke columns is strongly related to fire intensity and only loosely related to lapse rate and other measures of atmospheric stability. By conducting intense fires, managers can maintain air quality when atmospheric conditions are less than ideal for smoke dispersal.

Packer, Paul E.
1972. Site preparation in relation to environmental quality. *In* Proc. 1971 Annu. Meet. West. For. and Conserv. Assoc., Portland, Oreg. p. 23-28.

Current knowledge is summarized about objectives and methods of site preparation for forest regeneration in relation to environmental quality. The author discusses disposition of logging residue, redution or elimination of plant competition, preparation of mineral soil seedbeds, and provision of favorable microenvironment. Effects of prescribed fire, chemical treatment, and various mechanical methods of site preparation in realtion to air and water pollution are covered.

Packer, Paul E., and Bryan D. Williams.
1976. Logging and prescribed burning effects on the hydrologic and soil stability behavior of larch/Douglas-fir forests in the northern Rocky Mountains. Fire and Land Manage. Symp. [Missoula, Mont., Oct. 8-10, 1974]. *In* Proc. Tall Timbers Fire Ecol. Conf. 14:465-479.

The soil and hydrologic changes that occurred on 12 runoff plots at Miller for 7 years after treatment are described. There was a moderate increase in runoff and erosion following clearcutting and broadcast burning, primarily due to reduction of protective cover at or near the mineral soil surface. On all but south-facing slopes recovery was rapid, with runoff and erosion values returning to essentially pretreatment levels in less than 7 years. South slopes, with more intense burns and harsher site conditions, are slower to recover; here less drastic treatment is recommended.

Shearer, Raymond C.
1975. Seedbed characteristics in western larch forests after prescribed burning. USDA For. Serv. res. Pap. INT-167, 26 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Establishment of western larch seedlings is favored by site preparation that reduces the duff layer and sprouting of competing vegetation. The effectiveness of prescribed broadcast burning for seedbed preparation during the months of May through October was studied on clearcuts on all aspects at Miller Creek in northwest Montana. Greatest duff reduction, root mortality, and soil heating occurred when duff and soil water contents were lowest. Duff on north-facing slopes dries more slowly than on other aspects, requiring that the slash be burned in summer when the duff is dry to reduce the organic mantle and to prepare a satisfactory seedbed. Summers of frequent rainfall may prevent satisfactory preparation of seedbeds on north slopes. East-, south-, and west-facing slopes have a wider range of time when burning will prepare seedbeds suitable for natural regeneration.

Shearer, Raymond C.
1976. Early establishment of conifers following prescribed broadcast burning in western larch/Douglas-fir forests. Fire and Land Manage. Symp. [Missoula, Mont., Oct. 8-10, 1974]. *In* Proc. Tall Timbers Fire Ecol. Conf. 14:481-500.

Broadcast burning that reduced duff to within 1 cm of the mineral soil at random intervals provided seedbed conditions favorable for establishment of conifer regeneration in clearcuts at Miller and Newman. The interactions of seedbed condition, seed dispersal, and seed and seedling mortality are discussed in relation to natural regeneration. Seed-seedling ratios for several conifer species show relative regeneration success by aspect and habitat types. North- and east-facing slopes usually were quickly regenerated by conifers. South- and west-facing slopes require protection by shade to enhance conifer establishment.

Stickney, Peter F.
1980. Data base for post-fire succession, first 6 to 9 years, in Montana larch-fir forests. USDA For. Serv. Gen. Tech. Rep. INT-62, 133 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Baseline data on plant species cover ($m^2/0.01$ ha) and volume of space occupied ($m^3/0.01$ ha) for the initial 6 to 9 years of secondary forest succession following wildfire or clearcutting and broadcast slash burning are presented in tabular form for 20 larch/Douglas-fir sites in western Montana. Location, physical description, predisturbance stand, and details of disturbance are given for each site. These data, presented without interpretation, are available for analytical use by others in forest development modeling and forest management application.

U.S. GOVERNMENT PRINTING OFFICE 1981—779-027/M9789 Region No. 8

DeByle, Norbert V.
1981. Clearcutting and fire in the larch/Douglas-fir forests of western Montana—a multifaceted research summary. USDA For. Serv. Gen. Tech. Rep. INT-99, 73 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Logging slash on 73 clearcuts was broadcast burned over a wide range of conditions, achieving a broad array of fire intensities and effects. An intense wildfire was also evaluated. Fire effectiveness was measured and related to preburn conditions and fire intensity. Treatment effects on air quality, forest regeneration, vegetation recovery and development, small mammal populations, soil physical and chemical parameters, and runoff and erosion were measured and analyzed.

KEYWORDS: fuel reduction, fire effects, broadcast burning, fire intensity, forest regeneration, logging slash

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

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A COMPUTER SYSTEM FOR SCHEDULING FIRE USE

PART II: COMPUTER TERMINAL OPERATOR'S MANUAL

Larry S. Bradshaw and William C. Fischer

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Intermountain Forest and Range Experiment Station
U.S. Department of Agriculture, Forest Service

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RESEARCH SUMMARY

This manual provides program writeups for two separate but related computer programs: RXWTHR and RXBURN. These programs are components of a system designed to aid fire managers in predicting the probable occurrence of desired prescribed fire weather conditions.

The programs are stored in the USDA Forest Service Region 1 shared library at the Fort Collins Computer Center, Colo. They use National Fire Weather Data Data Library climatological data as a basic data source.

Complete information on program features, instructions for use, and program documentation are contained in a separate but related report entitled, "A Computer System for Scheduling Fire Use. Part I: The System" (Bradshaw and Fischer 1981).

USDA Forest Service
General Technical Report INT-100
February 1981

A COMPUTER SYSTEM FOR SCHEDULING FIRE USE
PART II: COMPUTER TERMINAL OPERATOR'S MANUAL

Larry S. Bradshaw and William C. Fischer

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
U.S. Department of Agriculture
Forest Service
Ogden, Utah 84401

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ADP PROGRAM WRITEUP: RXWTHR

Description

OGRAM	CSSG*R1LIB.RXWTHR
NGUAGE	ASCII Standard FORTRAN IV
CHINE	FCCC UNIVAC 1100
AGE	BATCH or DEMAND (132 characters)
OGRAMED	Refer to: Bradshaw, Larry S., and William C. Fischer. 1981. A computer system for scheduling fire use. Part I: The system. USDA For. Serv. Gen. Tech. Rep. INT-91. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Introduction

This writeup is designed to facilitate use of Program RXWTHR. Program RXWTHR is located the USDA Forest Service Region 1 shared library of the Fort Collins Computer Center. This ogram was developed cooperatively by Systems for Environmental Management (SEM) and the Fire Multiple Use Management Research, Development and Applications Program at the Northern Forest re Laboratory, Missoula, Mont. RXWTHR provides climatic summary, and two- and three-way -occurrence tables from data in the National Fire Weather Data Library (NFWDL). This writeup sumes the user is familar with data retrieval techniques from the NFWDL. Weather data is read om logical unit 15. If you are not familar with the data library, get details from Bradshaw d Fischer (1981), or from Furman and Brink (1975). This program may be used in the batch or MAND mode. The writeup covers only the batch mode. To run DEMAND, create a run stream via e @DATA and @ADD commands.

Input

User input to program RXWTHR is structured by (1) directive blocks and (2) information ragraphs. There are from one to five information paragraphs within each directive block. ere is one directive block for each station to be analyzed and for each multiple analysis of single station.

A directive block is always begun by the NUMBER OF STATIONS card and ended with the RUN ntrol card. The NUMBER OF STATIONS card is simply the number of stations (1-99) in card lumns 1 and 2. The RUN card is simply the word RUN in columns 1 to 3 on the last card of a rective block.

Information paragraphs within a directive block are set off by a control word and have om one to 15 trailing cards that provide information needed to execute the program. In WTHR these paragraphs are:

STATION	information (followed by three information cards)
ACTIVITY	information (followed by one information card)
SUMMARY	information (followed by one to 15 information cards)
CO-OCCUR	information (followed by one to five information cards)
DUFF	information (followed by two to five information cards)

e paragraphs may be entered in any order and are keyed by the capitalized words above beginng with column 1. Information that does not change from one directive block to the next or multiple analyses) should not be entered in directive blocks following its original claration.

Information to construct these directive blocks and paragraphs is taken from the User Information sheets provided by program users (exhibit 1). Card punching instructions are contained in exhibits 2, 3, 4, 5, and 6.

Job Control Language

The following defines the job control language (JCL) needed to get weather data from the National Fire Weather Data Library and execute program RXWTHR. If you do not know the location of the data file for the station to be analyzed, execute the following control commands:

```
@ASG,A FIREDATALIB*PROGRAMS.
@XQT FIREDATALIB*PROGRAMS.LISTFILES
```

Then pick the file that contains the station to be analyzed. If more than one station is to be analyzed, pick the file containing the <u>lowest station number</u>. The following sequence illustrat the JCL to get data and execute RXWTHR for the examples on pages 11-15.

```
 1.  @RUN,PRIORITY JOBNAME,ACCOUNT,QUALIFIER,TIME,PAGES
 2.  @ASG,A FIREDATALIB*PROGRAMS.
 3.  @ASG,A FIREDATALIB*21-24.
 4.  @USE 2.,FIREDATALIB*21-24.
 5.  @ASG,UP QUALIFIER*PHILIP.
 6.  @USE 15.,QUALIFIER*PHILIP.
 7.  @XQT FIREDATALIB*PROGRAMS.GETDATA2
 8.    24020755  24020777}
 9.    24300260  24300277}  ---->
10.  @EOF
11.  @FREE 2.
12.  @ASG,T 2.
13.  @ASG,A CSSG*R1LIB.
14.  @XQT CSSG*R1LIB.RXWTHR
       two directive blocks go here (see below)
15.  @EOF
16.  @FIN
```

Note: Actual formats are:
SSSSSSYB SSSSSSYE

SSSSSS = 6 digit station code
YB = Year data to begin
YE = Year data to end

Subsequent analysis of the same station within 6 days would replace commands 2 through 11 with:

```
@ASG,A QUALIFIER*PHILIP.
@USE 15., QUALIFIER*PHILIP.
```

to obtain the same data for analysis from mass storage at FCCC.

Example of Input Stream for Two-Station Analysis by RXWTHR

```
________
          02 (Number of Stations)

        { STATION

        {   WEST GLACIER   240207   3200   46 3

first   { YEARS       1955   1978

        { DATES       0601   0915
```

RXWTHR -- USER INFORMATION SHEET

Total Number Different Stations in This Run ______________

User's Name __________________, Subunit __________________________, Unit _______

Project[1/] ____

Fire Weather Station Information: Station name ______________________, No. ________

Elevation _________ ft., Latitude _________, Climate class[2/] _________, Slope class[3/] _________

Fuel model[4/] _________, Last frost [5/] __________, Grass type [5/]: annual _____, perennial _______

Year begin __________, Year end __________, Date begin ___________, Date end ___________

Site Adjustment Factors (if any):

Aspect _____ (1=north, 2=east, 3=south, 4=west), Site elevation ___________________ ft.

Canopy cover ________ (1=open, 2=closed)

Duff/Soil Horizon Information (if Duff Moisture selected. See User's Guide, appendix D):

Layer	Duff/Soil Type	Thickness
1	__________	_____ cm
2	__________	_____ cm
3	__________	_____ cm
4	__________	_____ cm
5	__________	_____ cm

1/ Use up to 80 characters

2/ See User's Guide, appendix C

3/ See User's Guide, appendix B

4/ For NFDRS indices only. See User's Guide, appendix A

5/ For NFDRS indices only

Summary Table(s) Requested (Select up to 15):

____ State of the weather

____ Temperature (degrees F)

____ Relative humidity (%)

____ Wind direction (8 point)

____ Wind speed (mi/h)

____ Max temperature (24 h, deg. F)

____ Min temperature (24 h, deg. F)

____ Max relative humidity (24 h, %)

____ Min relative humidity (24 h, %)

____ Precip duration (last 24 h)

____ Precip amount (24 h, 0.01 in)

____ 1 hour fuel moisture (%)

____ 10 hour fuel moisture (%)

____ NFDRS ERC

____ NFDRS BI

____ Duff Moisture (24 h average, %)

Co-occurrence Table(s) Requested (If 2-way table desired leave last space blank. If selected, Wind Direction must always be listed first.):

1 ______________________ with ______________________ with ______________________

2 ______________________ with ______________________ with ______________________

3 ______________________ with ______________________ with ______________________

4 ______________________ with ______________________ with ______________________

5 ______________________ with ______________________ with ______________________

xhibit 1.--RXWTHR User Information Sheet. Users' guide and appendixes A, B, C, and D refer to Bradshaw and Fischer (1981).

CARD PUNCHING & VERIFYING INSTRUCTIONS	Symbol	*Function	PROGRAM NAME RXWTHR
	D	Duplicate	PROGRAM NUMBER
	P	Punch	DATE
	S	Skip	SOURCE DOCUMENT CARD FORM USED
	V	Verify	PREPARED BY LARRY BRADSHAW
	L	Left Justify	PAGE 1 of 2

CARD FIELD	COLUMNS FROM	TO	NO. COLS.	FUNC. *	REMARKS
STATION INFORMATION PARAGRAPH ************************************	1	7	7	P	Punch STATION -- sets up reading sequence of next three cards
Station Name	1	16	16	P	Format 4A4, enter station name
Station Number	17	22	6	P	Format I6, enter AFFIRMS number
Station Elevation	24	28	5	P	Format F5.0, enter elevation (ft)
Station Latitude	30	31	2	P	Format I2, enter latitude (degrees)
NFDRS Fuel Model	33	33	1	P	Format A1, enter model
NFDRS Slope Class	35	35	1	P	Format I1, enter class (1-5)
Herbaceous Type	37	37	1	P	Format A1, enter A or P
NFDRS Climate Class	39	39	1	P	Format I1, enter class (1-4)
Date of Greenup *	41	44	4	P	Format I4, enter MMDD
REPEAT **	46	46	1	P	Format L1, enter T,F or blank
SAVE **	48	48	1	P	Format L1, enter T,F or blank
ADJUST ***	50	50	1	P	Format L1, enter T,F or blank
Site Aspect Code ***	52	52	1	P	Format I1, enter code (1-4)
Site Elevation ***	54	58	5	P	Format F5.0, enter elevation
Site Canopy Cover ***	60	60	1	P	Format I1, enter code (1-2)

* Needed only for runs with NFDRS INDICES

** SAVE is used to write first run computation to disk file (TAPE2), next run is then a REPEAT run and reads from TAPE2 skipping first directive block computations.

***Needed only if site adjustments are to be made. ADJUST turns the option on, the following three items specify adjustments.

Exhibit 2.--Card punching instructions for RXWTHR Station Information paragraph.

CARD PUNCHING & VERIFYING INSTRUCTIONS	Symbol	*Function	PROGRAM NAME RXWTHR	
	D	Duplicate	PROGRAM NUMBER	DATE
	P	Punch		
	S	Skip	SOURCE DOCUMENT CARD FORM USED	
	V	Verify		
	L	Left Justify	PREPARED BY LARRY BRADSHAW	PAGE 2 of 2

CARD FIELD	COLUMNS FROM	TO	NO. COLS.	FUNC. *	REMARKS
SECOND CARD AFTER "STATION" CONTROL CARD					
Years of analysis	1	5	5	P	Punch 'YEARS'
Beginning year	11	14	4	P	Enter 19YY
Ending year	17	20	4	P	Enter 19YY
THIRD CARD AFTER "STATION" CARD					
Dates	1	5	5	P	Punch 'DATES'
Beginning date	11	14	4	P	Enter MMDD to begin
Ending date	17	20	4	P	Enter MMDD to end
*********************** ***********************					
**** Remember that RXWTHR is limited to a 5-month analysis per execution.					
For analyses of more than 5 months, see page 10 of this report.					

xhibit 2.--continued

CARD PUNCHING & VERIFYING INSTRUCTIONS	Symbol D P S V L	*Function Duplicate Punch Skip Verify Left Justify	PROGRAM NAME RXWTHR PROGRAM NUMBER DATE SOURCE DOCUMENT CARD FORM USED PREPARED BY LARRY BRADSHAW PAGE 1 of 1

CARD FIELD	COLUMNS FROM	TO	NO. COLS.	FUNC. *	REMARKS
*********************** ***********************					
ACTIVITY INFORMATION PARAGRAPH					
ACTIVITY control word	1	8	8	P	Punch ACTIVITY -- this card sets up a
(This card is the first					reading sequence of one trailing card.
card of the paragraph.)					
ACTIVITY information	1	80	80	P	Enter any information you wish printed
(This is the second and					at the top of each page of output.
last card of the ACTIVITY					Input format is 20A4.
paragraph.)					
*********************** ***********************					

Exhibit 3.--Card punching instructions for RXWTHR Activity Information paragraph.

CARD PUNCHING & VERIFYING INSTRUCTIONS

Symbol	*Function
D	Duplicate
P	Punch
S	Skip
V	Verify
L	Left Justify

PROGRAM NAME RXWTHR	
PROGRAM NUMBER	DATE
SOURCE DOCUMENT CARD FORM USED	
PREPARED BY LARRY BRADSHAW	PAGE 1 of 1

CARD FIELD	COLUMNS FROM	COLUMNS TO	NO. COLS.	FUNC. *	REMARKS
*********************** ***********************					
SUMMARY INFORMATION PARAGRAPH					
SUMMARY control card (This is the first card of the paragraph.)	1	7	7	P	Punch SUMMARY -- sets up reading sequence.
SUMMARY information card(s)	6	25	20	P/L	Punch parameter from user information sheet. One card per parameter (up to 15 cards).
END paragraph control card (last card of paragraph)	1	3	3	P	Punch END -- ends input sequence.
*********************** ***********************					

Exhibit 4.--Card punching instructions for RXWTHR Summary Information paragraph.

CARD PUNCHING & VERIFYING INSTRUCTIONS	Symbol	*Function	PROGRAM NAME RXWTHR	
	D P S V L	Duplicate Punch Skip Verify Left Justify	PROGRAM NUMBER	DATE
			SOURCE DOCUMENT CARD FORM USED	
			PREPARED BY LARRY BRADSHAW	PAGE 1 of 1

CARD FIELD	COLUMNS		NO. COLS.	FUNC. *	REMARKS
	FROM	TO			
*********************** ***********************					
CO-OCCURRENCE INFORMATION PARAGRAPH					
CO-OCCUR CONTROL CARD	1	8	8	P	Enter CO-OCCUR
(first card of paragraph)					
CO-OCCUR parameter cards	6	25	20	L/P	Enter first parameter from information
(up to five)					sheet.
	31	50	20	L/P	Enter second parameter from information
(Repeat for each of one					sheet.
to five tables.)	56	75	20	L/P	Enter third (if requested) parameter
					from information sheet, otherwise leave
					blank.
End Paragraph input	1	3	3	P	Punch END
sequence last card of					
paragraph					
*********************** ***********************					

Exhibit 5.--Card punching instructions for RXWTHR Co-occurrence Information paragraph.

CARD PUNCHING & VERIFYING INSTRUCTIONS	Symbol	*Function	PROGRAM NAME RXWTHR	
	D	Duplicate	PROGRAM NUMBER	DATE
	P	Punch		
	S	Skip	SOURCE DOCUMENT CARD FORM USED	
	V	Verify		
	L	Left Justify	PREPARED BY LARRY BRADSHAW	PAGE 1 of 1

CARD FIELD	COLUMNS FROM	TO	NO. COLS.	FUNC. *	REMARKS
************************ ************************					
DUFF INFORMATION PARAGRAPH -----					
This paragraph is only entered when the DUFF MOISTURE option is requested in either a SUMMARY or CO-OCCUR table information paragraph.					
The paragraph consists of a DUFF control word card that also gives the number of layers of duff (NLAYER) and then NLAYER information cards giving the type of duff (via code) and the thickness of the layer.					
Card 1. DUFF control	1	4	4	P	Punch DUFF
word and NLAYER	12	12	1	P	Enter number of layers (I1).
DUFF information cards (one for each layer, NLAYER)					
Duff type	1	5	5	P	Punch type code from user information sheet. Format is F5.0, decimal is punched.
Layer thickness	6	10	5	P	Enter thickness. Format is F5.0, decimal is punched, units are centimeters.
************************ ************************					

Exhibit 6.--Card punching information for RXWTHR Duff Information paragraph.

```
          ACTIVITY
directive    BRIEF FIRE WEATHER SUMMARIES FOR WEST GLACIER HEADQUARTERS
          SUMMARY
             TEMPERATURE
block
             WIND DIRECTION
          END
          CO-OCCUR
             WIND DIRECTION          WIND SPEED
             TEMPERATURE             RELATIVE HUMIDITY       WIND SPEED
          END
          RUN
_________
         02
          STATION
second
          PHILIPSBURG RS 243002  5280 46 3
          YEARS    1960 1977
directive
          DATES    0501 0931
          ACTIVITY
block
             DEMONSTRATION OF RXWTHR INPUT AND OUTPUT FOR PHILIPSBURG RS
          RUN
_________
          @EOF
          @FIN
```

Exhibits 7 and 8 present user information necessary for this two-station analysis. Output from the second directive block is shown in exhibits 9, 10, 11, and 12.

Analysis of Stations with More Than Five Months Weather Data by RXWTHR

If two or more runs of RXWTHR are required to obtain a full season analysis, set the NUMBER OF STATION card value to one (01) and stack two or three (if 11 or 12 months of data are available) directive blocks and date of analysis cards (DATES) so that 5 months are covere in the first run. Then set the date of analysis card(s) in the following directive block's (blocks') STATION information sequence so that the entire season is covered in two or three passes through the data. (Setting the NUMBER OF STATION card to 01 rewinds the weather data [Tape 15] after each run [RUN]).

RXWTHR -- USER INFORMATION SHEET

Total Number Different Stations in This Run 02

User's Name COLONY, Subunit GLACIER NP, Unit NPS

Project[1/] Brief fire weather summaries for West Glacier headquarters

Fire Weather Station Information: Station name WEST GLACIER, No. 240207

Elevation 3200 ft., Latitude 46, Climate class[2/] 3, Slope class[3/] ____

Fuel model[4/] ____, Last frost [5/] ____, Grass type [5/]: annual ____, perennial ____

Year begin 1955, Year end 1978, Date begin 0601, Date end 0915

Site Adjustment Factors (if any):

Aspect ____ (1=north, 2=east, 3=south, 4=west), Site elevation ____ ft.

Canopy cover ____ (1=open, 2=closed)

Duff/Soil Horizon Information (if Duff Moisture selected. See User's Guide, appendix D):

Layer	Duff/Soil Type	Thickness
1		cm
2		cm
3		cm
4		cm
5		cm

1/ Use up to 80 characters

2/ See User's Guide, appendix C

3/ See User's Guide, appendix B

4/ For NFDRS indices only. See User's Guide, appendix A

5/ For NFDRS indices only

Summary Table(s) Requested (Select up to 15):

- ____ State of the weather
- X Temperature (degrees F)
- ____ Relative humidity (%)
- X Wind direction (8 point)
- ____ Wind speed (mi/h)
- ____ Max temperature (24 h, deg. F)
- ____ Min temperature (24 h, deg. F)
- ____ Max relative humidity (24 h, %)
- ____ Min relative humidity (24 h, %)
- ____ Precip duration (last 24 h)
- ____ Precip amount (24 h, 0.01 in)
- ____ 1 hour fuel moisture (%)
- ____ 10 hour fuel moisture (%)
- ____ NFDRS ERC
- ____ NFDRS BI
- ____ Duff Moisture (24 h average, %)

Co-occurrence Table(s) Requested (If 2-way table desired leave last space blank. If selected, Wind Direction must always be listed first.):

1 WIND DIRECTION with WIND SPEED with ____

2 TEMPERATURE with RELATIVE HUMIDITY with WIND SPEED

3 ____ with ____ with ____

4 ____ with ____ with ____

5 ____ with ____ with ____

Exhibit 7.--User information for example of two-station analysis, first directive block.

RXWTHR -- USER INFORMATION SHEET

Total Number Different Stations in This Run 02

User's Name BRADSHAW, Subunit FIRE LAB, Unit INT EXP STN

Project[1] Demonstration of RXWTHR output for Philipsburg Ranger Station

Fire Weather Station Information: Station name PHILIPSBURG RS, No. 243002

Elevation 5280 ft., Latitude 46, Climate class[2] 3, Slope class[3] ____

Fuel model[4] ____, Last frost [5] ____, Grass type [5] : annual ____, perennial ____

Year begin 1960, Year end 1977, Date begin 0501, Date end 0931

Site Adjustment Factors (if any):

Aspect ____ (1=north, 2=east, 3=south, 4=west), Site elevation ____ ft.

Canopy cover ____ (1=open, 2=closed)

Duff/Soil Horizon Information (if Duff Moisture selected. See User's Guide, appendix D):

Layer	Duff/Soil Type	Thickness
1		cm
2		cm
3		cm
4		cm
5		cm

1/ Use up to 80 characters

2/ See User's Guide, appendix C

3/ See User's Guide, appendix B

4/ For NFDRS indices only. See User's Guide, appendix A

5/ For NFDRS indices only

Summary Table(s) Requested (Select up to 15):

___ State of the weather
X Temperature (degrees F)
___ Relative humidity (%)
X Wind direction (8 point)
___ Wind speed (mi/h)
___ Max temperature (24 h, deg. F)
___ Min temperature (24 h, deg. F)
___ Max relative humidity (24 h, %)
___ Min relative humidity (24 h, %)
___ Precip duration (last 24 h)
___ Precip amount (24 h, 0.01 in)
___ 1 hour fuel moisture (%)
___ 10 hour fuel moisture (%)
___ NFDRS ERC
___ NFDRS BI
___ Duff Moisture (24 h average, %)

Co-occurrence Table(s) Requested (If 2-way table desired leave last space blank. If selected, Wind Direction must always be listed first.):

1 WIND DIRECTION with WIND SPEED with ____
2 TEMPERATURE with RELATIVE HUMIDITY with WIND SPEED
3 ____ with ____ with ____
4 ____ with ____ with ____
5 ____ with ____ with ____

Exhibit 8.--User information for example of two-station analysis, second directive block.

```
                    10 DAY AND MONTHLY SUMMARIES OF ***TEMPERATURE          ***

                    RELATIVE FREQUENCY OF OCCURRENCE OF DAILY VALUES (1500 MST)

                      DEMONSTRATION OF RXWTHR OUTPUT FOR PHILLIPSBURG RANGER STATION

                              PHILLIPSBURG RS  (243002)      1960-1977



                              TEMPERATURE              (F)

                   55     60     65     70     75     80     85     90     95
PERIOD     BELOW   TO     TO     TO     TO     TO     TO     TO     TO    AND
BEGINS      55     59     64     69     74     79     84     89     94  ABOVE    N. DAYS   MEAN    SD   MEDIAN       RANGE
--------------------------------------------------------------------------------------------------------------------------------

MAY  1      53.8   12.5   11.5   12.5    2.9    6.7                                    104   54.3  11.5     52.6       34  -  79
MAY 11      39.4   17.4   14.7   12.8    9.2    6.4                                    109   57.3  11.0     57.0       30  -  79
MAY 21      31.4   18.6   20.3   12.7   11.0    5.1     .8                             118   59.1  10.3     59.0       33  -  84
JUN  1      21.8   14.5   13.5   21.8   15.4    9.1    2.7                             110   62.8   9.8     64.0       39  -  82
JUN 11      25.7   16.5    7.3   18.3   13.8   10.1    3.7    4.6                      109   63.3  11.8     64.1       34  -  88
JUN 21      13.2   12.3    9.4   15.1   19.8   13.2   12.3    4.7                      106   67.7  11.6     69.0       38  -  87
JUL  1       1.4    5.8    5.8   12.3   20.3   29.0   19.6    5.1            .7        139   73.8   8.0     74.8       52  -  95
JUL 11       1.3    5.3    6.7   11.3   15.3   23.3   22.0   11.3    3.3               150   75.1   9.1     76.1       48  -  92
JUL 21        .6    1.2    4.9    8.5   10.9   23.6   29.7   19.4    1.2               165   78.0   7.5     79.1       52  -  90
AUG  1       1.9    4.4    3.9   12.6   15.4   20.1   21.4   15.1    3.8     .5        159   76.4   9.2     76.7       50  -  95
AUG 11       2.1    4.1    6.2    9.6   13.0   19.9   23.3   21.2     .7               145   76.5   9.3     77.8       45  -  91
AUG 21      11.3    8.1    8.1   11.9   13.1   22.5   15.6    6.9    1.9     .5        160   70.8  11.6     73.0       41  -  95
SEP  1      23.1    7.7          15.4   30.8           7.7    7.7    7.7                 13   67.4  14.7     69.6       45  -  90
--------------------------------------------------------------------------------------------------------------------------------

MAY         41.1   16.3   15.7   12.7    7.9    6.0     .3                             331   57.0  11.1     56.7       30  -  84
JUN         20.3   14.5   10.2   18.5   16.6   10.8    6.2    3.1                      325   64.6  11.3     65.4       34  -  88
JUL          1.1    4.0    5.7   10.6   15.2   25.2   24.1   12.4    1.5     .2        453   75.8   8.4     76.7       48  -  95
AUG          5.2    5.6    6.0   11.4   14.2   20.9   20.0   14.2    2.2     .4        465   74.5  10.5     75.8       41  -  95
SEP         23.1    7.7          15.4   30.8           7.7    7.7    7.7                 13   67.4  14.7     69.6       45  -  90
--------------------------------------------------------------------------------------------------------------------------------
```

Exhibit 9.--Program RXWTHR temperature summary output for second directive block in two-station analysis example.

```
                    10 DAY AND MONTHLY SUMMARIES OF ***WIND DIRECTION        ***

                    RELATIVE FREQUENCY OF OCCURRENCE OF DAILY VALUES (1500 MST)

                      DEMONSTRATION OF RXWTHR OUTPUT FOR PHILLIPSBURG RANGER STATION

                              PHILLIPSBURG RS  (243002)      1960-1977



                   WIND DIRECTION

PERIOD
BEGINS      CALM     NE      E     SE      S     SW      W     NW      N              N. DAYS             MODE
--------------------------------------------------------------------------------------------------------------------------------

MAY  1       1.9    8.7    1.9    1.9    2.9   26.9   19.2   28.8    7.7                  104             NW
MAY 11       1.8    8.3    1.8    1.8    1.8   22.9   20.2   27.5   13.8                  109             NW
MAY 21        .8    3.4     .8    2.5     .8   29.7   12.7   38.1   11.0                  118             NW
JUN  1       5.5    5.5    3.6    4.5          18.2   14.5   39.1    9.1                  110             NW
JUN 11       3.7    1.8    4.6    3.7    1.8   26.6   12.8   30.3   14.7                  109             NW
JUN 21       5.7    4.7    2.8    1.9    3.8   25.5   17.9   26.4   11.3                  106             NW
JUL  1       2.9    5.8    2.2    2.9     .7   25.4   15.9   29.7   14.5                  138             NW
JUL 11       3.3    5.3    2.0    2.0    7.3   22.0   15.3   27.3   15.3                  150             NW
JUL 21       1.2    4.8    1.2    2.4    3.0   20.6   20.0   37.6    9.1                  165             NW
AUG  1       1.9    9.4    1.3    4.4    1.9   30.2   12.6   30.8    7.5                  159             NW
AUG 11       2.7    1.4    1.4    1.4    1.4   28.1   17.8   39.7    6.2                  145             NW
AUG 21       2.5    3.8     .6    2.5    8.8   23.1   18.8   32.5    7.5                  160             NW
SEP  1                                   7.7   15.4   46.2   30.8                          13              W
--------------------------------------------------------------------------------------------------------------------------------

MAY          1.5    6.6    1.5    2.1    1.8   26.6   17.2   31.7   10.9                  331             NW
JUN          4.9    4.0    3.7    3.4    1.8   23.4   15.1   32.0   11.7                  325             NW
JUL          2.4    5.3    1.8    2.4    3.8   22.5   17.2   31.8   12.8                  453             NW
AUG          2.4    4.9    1.1    2.8    4.1   27.1   16.3   34.2    7.1                  465             NW
SEP                                      7.7   15.4   46.2   30.8                          13              W
--------------------------------------------------------------------------------------------------------------------------------
```

Exhibit 10.--Program RXWTHR wind direction summary output for second directive block in two-station analysis example.

```
          WIND DIRECTION        -  WIND SPEED

               PERCENT FREQUENCY OF CO-OCCURRENCE
                    GIVEN TO TENTHS PERCENT

               PHILLIPSBURG RS  (243002)     1960-1977

    DEMONSTRATION OF RXWTHR OUTPUT FOR PHILLIPSBURG RANGER STATION



          ** MAY **

                     WIND SPEED           MPH
                    3    6    9   12   15   18   21  24    28 I
  DIR      BELOW   TO   TO   TO   TO   TO   TO   TO  TO   AND I
               3    5    8   11   14   17   20   23  27 ABOVE I  TOTAL I
----------I---------------------------------------------------I--------I
     CALM I  1.5                                              I    1.5 I
       NE I  2.7  1.8   .3  1.2        .3        .3           I    6.6 I
        E I   .3   .6   .3        .3                          I    1.5 I
       SE I   .3   .9   .6        .3                          I    2.1 I
        S I   .3   .3   .3   .9                               I    1.8 I
       SW I   .9  9.7  5.1  4.2  3.6  2.1   .9                I   26.6 I
        W I  1.8  1.8  6.6  2.4  3.6   .9                     I   17.2 I
       NW I  1.5  9.4  7.9  4.8  3.6  3.5   .6   .3           I   31.7 I
        N I   .3  1.5  3.3  3.0  1.8   .5   .3                I   10.9 I
----------I---------------------------------------------------I--------I
    TOTAL I  9.7 26.0 24.5 16.5 13.3  7.5  1.8   .5  0.    0. I  100.0 I NUMBER OF DAYS   331


          ** JUN **

                     WIND SPEED           MPH
                    3    6    9   12   15   18   21  24    28 I
  DIR      BELOW   TO   TO   TO   TO   TO   TO   TO  TO   AND I
               3    5    8   11   14   17   20   23  27 ABOVE I  TOTAL I
----------I---------------------------------------------------I--------I
     CALM I  4.9                                              I    4.9 I
       NE I   .3  1.8   .6   .9   .3                          I    4.0 I
        E I   .3   .9  1.2   .9   .3                          I    3.7 I
       SE I   .6  1.2   .6   .3        .5                     I    3.4 I
        S I         .9   .3        .6                          I    1.8 I
       SW I  4.9  6.5  3.1  4.3  1.8  1.2  1.5                I   23.4 I
        W I   .6  4.6  2.8  3.1  3.7   .3                     I   15.1 I
       NW I  2.8  7.7  8.9  6.8  4.9   .5   .3                I   32.0 I
        N I   .3  2.2  4.0  1.5   .9  2.5             .3      I   11.7 I
----------I---------------------------------------------------I--------I
    TOTAL I 14.8 25.8 21.5 17.8 12.6  5.2  1.8   0.  .3    0. I  100.0 I NUMBER OF DAYS   325
```

Exhibit 11.--Program RXWTHR two-way co-occurrence output (wind direction and windspeed) for second directive block in two-station analysis example.

```
                                      TEMPERATURE              - RELATIVE HUMIDITY         - WIND SPEED
                                           PERCENT FREQUENCY OF CO-OCCURRENCE, GIVEN TO TENTHS PERCENT
PHILLIPSBURG RS  (243002)
** MAY **        1960-1977

                                      DEMONSTRATION OF RXWTHR OUTPUT FOR PHILLIPSBURG RANGER STATION


                    WIND SPEED               LT    6 MPH                  I        WIND SPEED                 6 - 11 MPH                I
                                                                          I                                                             I
                      RELATIVE HUMIDITY         %                         I          RELATIVE HUMIDITY         %                        I
                     10    20    30    40    50    60    70    80     90  I        10    20    30    40    50    60    70    80     90  I
  TEMP       BELOW   TO    TO    TO    TO    TO    TO    TO    TO  AND    I BELOW  TO    TO    TO    TO    TO    TO    TO    TO  AND    I
  (F)       I  10    19    29    39    49    59    69    79    89  ABOVE  I  10    19    29    39    49    59    69    79    89  ABOVE  I
------------I-------------------------------------------------------------I-------------------------------------------------------------I
   LT    55 I                      .6   1.5   3.6   1.2   3.3   2.4   3.0 I                .3   1.2   3.3   2.4   3.6   3.0   2.1    .9 I
 55 -    59 I                .6    .6   2.4   1.2    .6          .3       I          .6   1.2   3.3   1.2    .3    .3                   I
 60 -    64 I                .6   1.8   1.8    .6    .3    .3             I          .3   1.5   2.7    .6    .9                         I
 65 -    69 I               1.2   2.1    .6          .3                   I          .6   1.8   1.2    .9                               I
 70 -    74 I          .6    .9    .6          .3                         I          .3   2.1    .9    .3                               I
 75 -    79 I          .3   1.2          .3                               I         1.5   1.2    .3                                     I
 80 -    84 I          .3                                                 I                                                             I
 85 -    89 I                                                             I                                                             I
 90 -    94 I                                                             I                                                             I
   GE    95 I                                                             I                                                             I
------------I-------------------------------------------------------------I-------------------------------------------------------------I
   TOTAL    I  0.     1.2   4.5   5.7   6.6   5.7   2.4   3.6   2.7   3.0 I  0.     3.3   8.2   9.7   5.3   3.6   3.9   3.0   2.1    .9 I

  TEMP      I       WIND SPEED                12 - 17 MPH                 I       WIND SPEED                18 - 23 MPH                 I
------------I-------------------------------------------------------------I-------------------------------------------------------------I
   LT    55 I                      .9   1.8    .9   1.5   1.2    .9       I                      .3    .3          .3    .3             I
 55 -    59 I                .6    .9    .9    .6    .3                   I                      .3                                     I
 60 -    64 I    .3          .9   1.2    .6          .3    .3             I                      .3          .3                         I
 65 -    69 I                .9   1.8    .3    .3          .3             I                      .3                                     I
 70 -    74 I               1.8                                           I                                                             I
 75 -    79 I               1.2                                           I                                                             I
 80 -    84 I                                                             I                                                             I
 85 -    89 I                                                             I                                                             I
 90 -    94 I                                                             I                                                             I
   GE    95 I                                                             I                                                             I
------------I-------------------------------------------------------------I-------------------------------------------------------------I
   TOTAL    I    .3   0.    5.4   4.8   3.5   1.8   2.1   1.8    .9   0.  I  0.     0.    0.    1.2    .3    .3    .3    .3   0.    0.  I

  TEMP      I       WIND SPEED               GE  24 MPH                   I   TOTAL I
------------I-------------------------------------------------------------I---------I
   LT    55 I                                                             I    41.1 I
 55 -    59 I                                                             I    16.3 I
 60 -    64 I                                                             I    15.7 I
 65 -    69 I                                                             I    12.7 I
 70 -    74 I                                                             I     7.9 I
 75 -    79 I                                                             I     6.0 I
 80 -    84 I                                                             I      .3 I
 85 -    89 I                                                             I     0.  I
 90 -    94 I                                                             I     0.  I
   GE    95 I                                                             I     0.  I
------------I-------------------------------------------------------------I---------I
   TOTAL    I  0.     0.    0.    0.    0.    0.    0.    0.    0.    0.  I   100.0 I NUMBER OF DAYS    331
```

Exhibit 12.--Program RXWTHR three-way co-occurrence output (temperature, relative humidity and windspeed) for second directive block in two-station analysis example.

Error Messages

1. Control sequence incorrect, program aborted.

   Cause: A control card was read that was uninterpretable by the program's internal dictionary. Misspelled control words or failure to start the word in column 1 of the control card are the most common causes. Can also be caused by not placing an END card at the end of an option series.

2. No summary or co-occurrence option specified, program aborted.

   Cause: There is neither a SUMMARY nor a CO-OCCUR control card in the input stream.

3. Station numbers on descriptor card and data file do not match, program aborted.

   Cause: Keypunch error on STATION card following STATION control card, or error in data file structure. Remember that stations must be analyzed in ascending order.

4. At least one summary option card is incorrect, program aborted.

   Cause: One of the option cards trailing the SUMMARY control card is misspelled or does not begin in column 6.

5. At least one co-occurrence option card is incorrect, program aborted.

   Cause: One of the option cards trailing the CO-OCCUR control card has a misspelled word, or the words do not begin in the correct columns. The correct columns are 6 and 31 for two-way tables, and 6, 31, and 56 for three-way tables.

6. Difference between site and AFFIRMS station greater than 2000 feet, no adjustments made.

   Cause: When using ADJUST option, elevation differences are limited to 2000 feet. Program executes, but without any site adjustments.

7. More than 5 months weather summary requested, only first 5 months processed.

   Cause: Self-explanatory -- Split data into two or three sections.

Output Quantity

For each station, the following output is produced:

SUMMARY tables: One (1) page for each parameter requested.

CO-OCCURRENCE tables:

Two-way: One (1) page for each table per 2-month analysis (for example, a two-way table from May through August will have two pages of output)

Three-way: One (1) page for each table for each month's analysis (for example, a three-way table from May through September will produce five pages of output)

Cost Estimates

For a typical RXWTHR run (one station, 5-month analysis, five summary tables, two to three co-occurrence tables) a user can expect costs and resource use as outlined below:

Run Priority	Cost	CAU (sec)	Resource time (sec)
DEMAND	\$6.00 - \$7.00	14 - 15	22 - 25
L	\$3.00 - \$4.00	14 - 15	22 - 25
M	\$2.00 - \$3.00	14 - 15	22 - 25
P	\$1.00 - \$2.00	14 - 15	22 - 25

ADP PROGRAM WRITEUP: RXBURN

Description

PROGRAM	CSSG*R1LIB.RXBURN
LANGUAGE	ASCII Standard FORTRAN IV
MACHINE	FCCC UNIVAC 1100
USAGE	BATCH or DEMAND (132 characters)
PROGRAMED	Refer to: Bradshaw, Larry S., and William C. Fischer. 1981. A computer system for scheduling fire use. Part I: the system. USDA For. Serv. Gen. Tech. Rep. INT-91. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Introduction

This writeup is designed to facilitate use of program RXBURN. This program is located in the USDA Forest Service Region 1 shared library at the Fort Collins Computer Center. RXBURN summarizes occurrence frequencies of user-defined prescribed fire conditions. The program operates on data from the National Fire Weather Data Library (NFWDL). This writeup assumes the user is familiar with techniques for accessing this data. Weather data are read from logical unit 15. If you are not familiar with these procedures see Bradshaw and Fischer (1980) or Furman and Brink (1975). This program may be used in either the batch or demand mode. Batch is covered in this writeup. Demand users should create run streams via @DATA and @ADD commands and run programs the same as batch.

Input

User input to RXBURN is structured by (1) directive blocks and (2) by information paragraphs within the directive blocks. There are from one to five information paragraphs within each directive block. Multiple-station or prescription analysis is obtained by "stacking" directive blocks.

A directive block is set off by a NUMBER OF STATIONS card and ended by a RUN card. The NUMBER OF STATIONS card is simply a card with the number of stations in columns 1 and 2. Up to 99 stations may be analyzed in a single run. The format is I2. The RUN card is simply the word RUN in columns 1 through 3 after all information has been read in the information paragraphs.

Information paragraphs within the directive blocks are set off by a control word beginning in the first column of the card and are followed by from one to 15 information cards, depending on the type of information.

Program RXBURN accepts the following words to set off information paragraphs:

STATION	information (followed by three information cards)
ACTIVITY	information (followed by one information card)
IDENTIFY	information (followed by one information card)
PRESCRIBE	information (followed by one to 15 information cards)
DUFF	information (followed by from two to five information cards)

The paragraphs may be entered in any order within a directive block, and information not changing from one directive block to the next (multiprescription or station analyses) does not need to be reentered in subsequent directive blocks.

Information needed to construct these directive blocks is taken from the user information sheets provided by program users (exhibit 13). Card punching instructions are contained in exhibits 14, 15, 16, 17, and 18.

Job Control Language

The following defines the job control language (JCL) needed to get weather data from the National Fire Weather Data Library and execute program RXBURN. If you do not know the location of the data file for the station to be analyzed, execute the following control commands:

```
@ASG,A FIREDATALIB*PROGRAMS.
@XQT FIREDATALIB*PROGRAMS.LISTFILES
```

Then pick the file that contains the station to be analyzed. If more than one station is to be analyzed, pick the file containing the lowest station number. The following sequence illustrates the JCL to get data and execute RXBURN for the examples on pages 27-30.

```
 1.  @RUN,PRIORITY JOBNAME,ACCOUNT,QUALIFIER,TIME,PAGES
 2.  @ASG,A FIREDATALIB*PROGRAMS.
 3.  @ASG,A FIREDATALIB*21-24.
 4.  @USE 2.,FIREDATALIB*21-24.
 5.  @ASG,UP QUALIFIER*PHILIP
 6.  @USE 15.,QUALIFIER*PHILIP
 7.  @XQT FIREDATALIB*PROGRAMS.GETDATA2
 8.  24300260  24300277
 9.  @EOF
10.  @FREE 2.
11.  @ASG,T 2.
12.  @ASG,A CSSG*R1LIB.
13.  @XQT CSSG*R1LIB.RXBURN
14.  @EOF
15.  @FIN
```

Note: Actual formats are:
SSSSSSYB SSSSSSYE

SSSSSS = 6 digit station code
YB = Year data to begin
YE = Year data to end

Subsequent analysis of the same station within six days would replace commands 2 through 11 with:

```
@ASG,A QUALIFIER*PHILIP.
@USE 15., QUALIFIER*PHILIP.
```

to obtain the same data for analysis from mass storage at FCCC.

RXBURN -- USER INFORMATION SHEET

Total Number Different Stations in This Run ____________________

User's Name __________________, Subunit ____________________________, Unit ___________

Project[1] ____

Fire Weather Station Information: Station name _________________________, No. _______

Elevation _________ ft., Latitude ________, Climate class[2] ________, Slope class[3] ___________

Fuel model[4] _______, Last frost[5] _____________, Grass type[5]: annual ______, perennial ______

Year begin _________, Year end ____________, Date begin ___________, Date end ___________

Site Adjustment Factors (if any):

Aspect _______ (1=north, 2=east, 3=south, 4=west), Site elevation _____________ ft.

Canopy cover ________ (1=open, 2=closed)

Duff/Soil Horizon Information (if Duff Moisture selected. See User's Guide, Appendix D):

Layer	Duff/Soil Type	Thickness
1	__________	_____ cm
2	__________	_____ cm
3	__________	_____ cm
4	__________	_____ cm
5	__________	_____ cm

[1] Use up to 80 characters

[2] See User's Guide, appendix C

[3] See User's Guide, appendix B

[4] For NFDRS indicies only. See User's Guide, appendix A

[5] For NFDRS indices only

Prescription Factor Selections (Check and set limits for up to 15 factors.):

Factor	Preferable Rx Minimum	Preferable Rx Maximum	Acceptable Rx Minimum	Acceptable Rx Maximum
____ State of the weather				
____ Temperature (deg. F)				
____ Relative humidity (%)				
____ Wind direction (8 point)				
____ Wind speed (mi/h)				
____ Max temperature (24 h, deg. F				
____ Min temperature (24 h, deg. F)				
____ Max relative humidity (24 h, %)				
____ Min relative humidity (24 h, %)				
____ Days since last precipitation				
____ Precip amount (24 h, 0.01 in)				
____ 1 hour fuel moisture (%)				
____ 10 hour fuel moisture (%)				
____ NFDRS ERC				
____ NFDRS BI				
____ Duff moisture (24 h average, %)				

Exhibit 13.--RXBURN User Information Sheet. User's guide and appendixes A, B, C, and D refer to Bradshaw and Fischer (1981).

CARD PUNCHING & VERIFYING INSTRUCTIONS

Symbol	*Function
D	Duplicate
P	Punch
S	Skip
V	Verify
L	Left Justify

PROGRAM NAME RXBURN

PROGRAM NUMBER

DATE

SOURCE DOCUMENT CARD FORM USED

PREPARED BY LARRY BRADSHAW

PAGE 1 of 2

CARD FIELD	COLUMNS FROM	TO	NO. COLS.	FUNC. *	REMARKS
STATION INFORMATION PARAGRAPH*************	1 *****	7 *****	7 *****	P ******	Punch STATION -- sets up reading sequence of next three cards
Station Name	1	16	16	P	Format 4A4, enter station name
Station Number	17	22	6	P	Format I6, enter AFFIRMS number
Station Elevation	24	28	5	P	Format F5.0, enter elevation (ft)
Station Latitude	30	31	2	P	Format I2, enter latitude (degrees)
NFDRS Fuel Model	33	33	1	P	Format A1, enter model
NFDRS Slope Class	35	35	1	P	Format I1, enter class (1-5)
Herbaceous Type	37	37	1	P	Format A1, enter A or P
NFDRS Climate Class	39	39	1	P	Format I1, enter class (1-4)
Date of Greenup *	41	44	4	P	Format I4, enter MMDD
REPEAT **	46	46	1	P	Format L1, enter T,F or blank
SAVE **	48	48	1	P	Format L1, enter T,F or blank
ADJUST ***	50	50	1	P	Format L1, enter T,F or blank
Site Aspect Code ***	52	52	1	P	Format I1, enter code (1-4)
Site Elevation ***	54	58	5	P	Format F5.0, enter elevation
Site Canopy Cover ***	60	60	1	P	Format I1, enter code (1-2)

* Needed only for runs with NFDRS INDICES

** SAVE is used to write first run computation to disk file (TAPE2), next run is then a REPEAT run and reads from TAPE2 skipping first directive block computations.

*** Needed only if site adjustments are to be made. ADJUST turns the option on, the following three items specify adjustments.

Exhibit 14.--Card punching instructions for RXBURN Station Information paragraph.

CARD PUNCHING & VERIFYING INSTRUCTIONS	Symbol D P S V L	*Function Duplicate Punch Skip Verify Left Justify	PROGRAM NAME RXBURN
			PROGRAM NUMBER / DATE
			SOURCE DOCUMENT CARD FORM USED
			PREPARED BY LARRY BRADSHAW / PAGE 2 of 2

CARD FIELD	COLUMNS FROM	TO	NO. COLS.	FUNC. *	REMARKS
SECOND CARD AFTER "STATION" CONTROL CARD					
Years of analysis	1	5	5	P	Punch 'YEARS'
Beginning year	11	14	4	P	Enter 19YY
Ending year	17	20	4	P	Enter 19YY
THIRD CARD AFTER "STATION" CARD					
Dates	1	5	5	P	Punch 'DATES'
Beginning date	11	14	4	P	Enter MMDD to begin
Ending date	17	20	4	P	Enter MMDD to end
************************ ************************					

Exhibit 14.--(continued)

CARD PUNCHING & VERIFYING INSTRUCTIONS	Symbol	*Function
	D	Duplicate
	P	Punch
	S	Skip
	V	Verify
	L	Left Justify

PROGRAM NAME RXBURN

PROGRAM NUMBER

DATE

SOURCE DOCUMENT CARD FORM USED

PREPARED BY LARRY BRADSHAW

PAGE 1 of 1

CARD FIELD	COLUMNS		NO. COLS.	FUNC. *	REMARKS
	FROM	TO			
************************ ************************					
ACTIVITY INFORMATION PARAGRAPH					
ACTIVITY control word	1	8	8	P	Punch ACTIVITY -- this card sets up a
(this card is the first					reading sequence of one trailing card.
card of the paragraph)					
ACTIVITY information	1	80	80	P	Enter any information you wish printed
(this is the second and					at the top of each page of output.
last card of the ACTIVITY					Input format is 20A4.
paragraph)					
************************ ************************					

Exhibit 15.--Card punching instructions for RXBURN Activity Information paragraph.

CARD PUNCHING & VERIFYING INSTRUCTIONS	Symbol	*Function	PROGRAM NAME RXBURN	
	D	Duplicate	PROGRAM NUMBER	DATE
	P	Punch	SOURCE DOCUMENT CARD FORM USED	
	S	Skip		
	V	Verify	PREPARED BY LARRY BRADSHAW	PAGE 1 of 1
	L	Left Justify		

CARD FIELD	COLUMNS FROM	COLUMNS TO	NO. COLS.	FUNC. *	REMARKS
*********************** ***********************					
IDENTIFY INFORMATION PARAGRAPH					
Card 1	1	8	8	P	Punch IDENTIFY
Card 2 information input					
User name	1	20	20	P	Enter user's name
District	21	40	20	P	Enter district
Forest	41	60	20	P	Enter forest
*********************** ***********************					

Exhibit 16.--Card punching instructions for RXBURN identify Information paragraph.

CARD PUNCHING & VERIFYING INSTRUCTIONS	Symbol	*Function	PROGRAM NAME RXBURN	
	D	Duplicate	PROGRAM NUMBER	DATE
	P	Punch	SOURCE DOCUMENT CARD FORM USED	
	S	Skip		
	V	Verify	PREPARED BY LARRY BRADSHAW	PAGE __ of __
	L	Left Justify		

CARD FIELD	COLUMNS FROM	COLUMNS TO	NO. COLS.	FUNC. *	REMARKS
*********************** ***********************					
PRESCRIPTION INFORMATION PARAGRAPH -- defines prescriptions for program analysis.					
The first card sets up a reading sequence of NPARM trailing cards. NPARM has a value					
from 1 to 15.					
Card 1. PRESCRIBE -- NPARM	1	9	9	P	Punch PRESCRIBE
enter NPARM	11	12	2	P	Enter total number of parameters in the
					prescription. Format I2, right
					justified.
Information card(s) -- one for each prescription parameter.					
Parameter	6	30	25	P/L	Enter factor from information sheet.
Preferred Minimum Value	33	35	3	P	Enter value (right justified)
Preferred Maximum Value	38	40	3	P	Enter value (right justified)
Acceptable Minimum Value	43	45	3	P	Enter value (right justified)
Acceptable Maximum Value	48	50	3	P	Enter value (right justified)
*********************** ***********************					

Exhibit 17.--Card punching instructions for RXBURN Prescriptions Information paragraph.

CARD PUNCHING & VERIFYING INSTRUCTIONS	Symbol	*Function	PROGRAM NAME RXBURN	
	D P S V L	Duplicate Punch Skip Verify Left Justify	PROGRAM NUMBER	DATE
			SOURCE DOCUMENT CARD FORM USED	
			PREPARED BY LARRY BRADSHAW	PAGE 1 of 1

CARD FIELD	COLUMNS FROM	COLUMNS TO	NO. COLS.	FUNC. *	REMARKS
********************** **********************					

DUFF INFORMATION PARAGRAPH ----

This paragraph is only entered when the DUFF MOISTURE option is requested as a parameter in the PRESCRIPTION information paragraph.

The paragraph consists of a DUFF control word card that also gives the number of layers of duff (NLAYER) and then NLAYER information cards giving the type of duff (via code) and the thickness of the layer.

CARD FIELD	COLUMNS FROM	COLUMNS TO	NO. COLS.	FUNC. *	REMARKS
Card 1. DUFF control	1	4	4	P	Punch DUFF
word and NLAYER	12	12	1	P	Enter number of layers (I1)

DUFF information cards (one for each layer, NLAYER)

CARD FIELD	COLUMNS FROM	COLUMNS TO	NO. COLS.	FUNC. *	REMARKS
Duff type	1	5	5	P	Punch type code from user information sheet. Format is F5.0, decimal is punched.
Layer Thickness	6	10	5	P	Enter thickness. Format is F5.0, decimal is punched, units are centimeters.
********************** **********************					

Exhibit 18.--Card punching instructions for RXBURN Duff Information paragraph.

Example of Input Stream for One Prescription

```
01

STATION

PHILIPSBURG RS 243002  5280 46 3

YEARS     1960  1977

DATES     0510  1101

ACTIVITY

   DEMONSTRATION OF RXBURN OUTPUT FOR PHILIPSBURG RANGER STATION

IDENTIFY

LARRY BRADSHAW      FIRE LAB        MONTANA

PRESCRIBE  03

     TEMPERATURE                65     75     60     80

     RELATIVE HUMIDITY          20     30     20     55

     WIND SPEED                  4      9      0     15

RUN

@EOF

@FIN
```

Exhibit 19 presents user information necessary for this example. Output is shown in exhibits 20, 21, 22, and 23.

Multiple Prescription Analysis

Program RXBURN is structured such that two or more prescription conditions may be analyzed for frequency of occurrence in one run on the same weather station.

This is accomplished by use of the SAVE and REPEAT options on the station information card in the STATION paragraph. The first directive block stores computed and observed parameter values by setting the SAVE option to TRUE. This is done with a "T" in column 48 of the station information card.

Stored computations are then used in subsequent directive blocks, which does away with the need to reread and compute all data for a station. This is accomplished by a "T" in column 46 of the second directive block. Third and subsequent directive blocks do not need the STATION paragraph entered. Remember, there is one directive block for each prescription analysis.

RXBURN -- USER INFORMATION SHEET

Total Number Different Stations in This Run 01

User's Name BRADSHAW, Subunit FIRE LAB, Unit INT EXP STN

Project[1/] Demonstration of RXBURN output for Philipsburg Ranger Station

Fire Weather Station Information: Station name Philipsburg RS, No. 243002

Elevation 5280 ft., Latitude 46, Climate class[2/] 3, Slope class[3/] ____

Fuel model[4/] ____, Last frost[5/] ____, Grass type[5/]: annual ____, perennial ____

Year begin 1960, Year end 1977, Date begin 0501, Date end 1101

Site Adjustment Factors (if any):

Aspect ____ (1=north, 2=east, 3=south, 4=west), Site elevation ____ ft.

Canopy cover ____ (1=open, 2=closed)

Duff/Soil Horizon Information (if Duff Moisture selected. See User's Guide, Appendix D):

Layer	Duff/Soil Type	Thickness
1		cm
2		cm
3		cm
4		cm
5		cm

[1/] Use up to 80 characters

[2/] See User's Guide, appendix C

[3/] See User's Guide, appendix B

[4/] For NFDRS indicies only. See User's Guide, appendix A

[5/] For NFDRS indices only

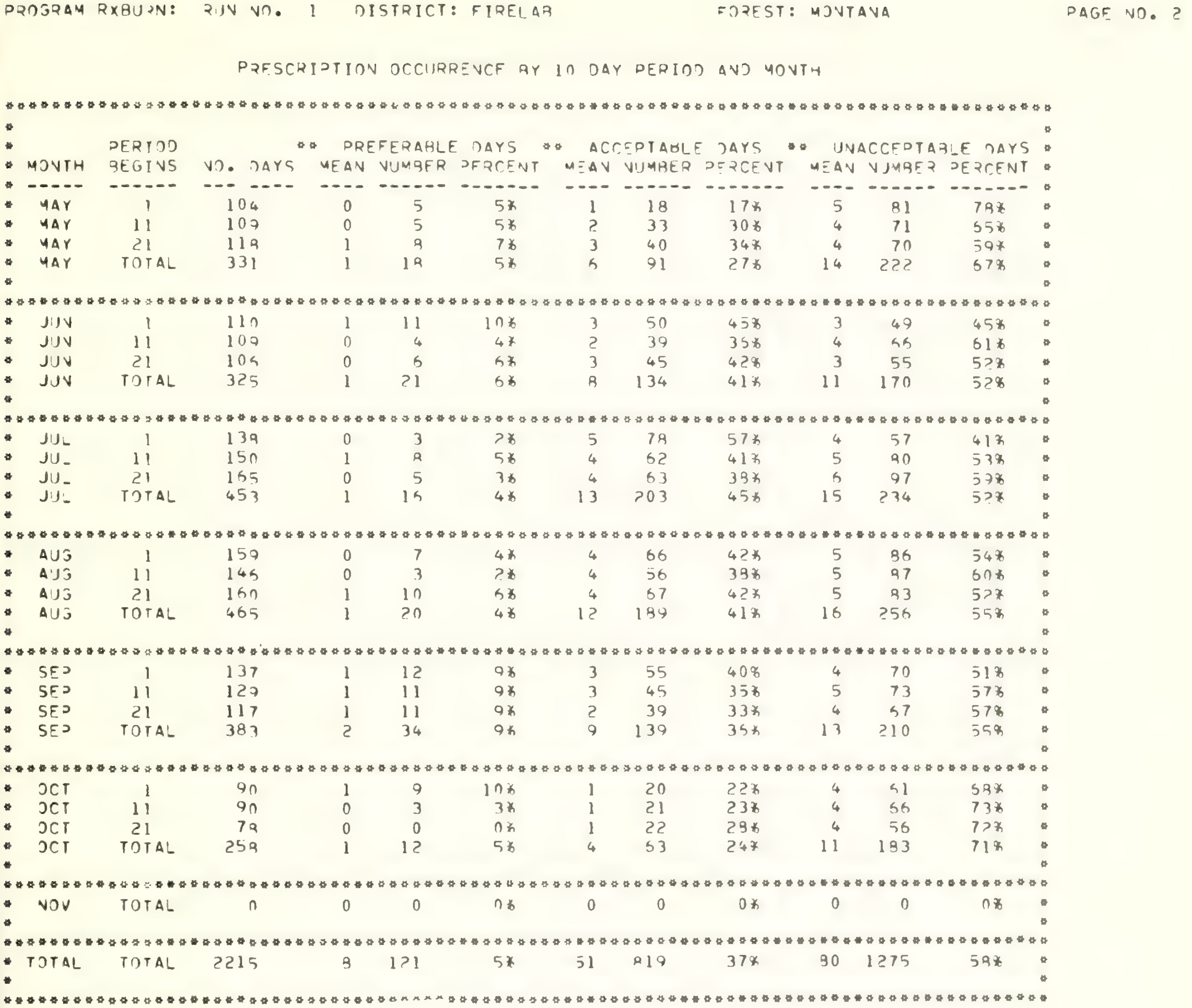
Prescription Factor Selections (Check and set limits for up to 15 factors.):

	Factor	Preferable Rx Minimum	Preferable Rx Maximum	Acceptable Rx Minimum	Acceptable Rx Maximum
	State of the weather				
X	Temperature (deg. F)	65	75	60	80
X	Relative humidity (%)	20	30	20	55
	Wind direction (8 point)				
x	Wind speed (mi/h)	4	9	0	15
	Max temperature (24 h, deg. F)				
	Min temperature (24 h, deg. F)				
	Max relative humidity (24 h, %)				
	Min relative humidity (24 h, %)				
	Days since last precipitation				
	Precip amount (24 h, 0.01 in)				
	1 hour fuel moisture (%)				
	10 hour fuel moisture (%)				
	NFDRS ERC				
	NFDRS BI				
	Duff moisture (24 h average, %)				

Exhibit 19.--User information sheet for one prescription example.

```
PROGRAM RXBURN:  RUN NO.  1   DISTRICT: FIRELAB                FOREST: MONTANA                   PAGE NO. 1

*******************************************************************************************
*                                                                                         *
*       DEMONSTRATION OF RXBURN OUTPUT FOR PHILLIPSBURG RANGER STATION                    *
*                                                                                         *
*******************************************************************************************

AFFIRMS STATION NAME: PHILLIPSBURG RS                  NATIONAL FOREST:  MONTANA
      STATION NUMBER: 243002                                  DISTRICT:  FIRELAB
    ELEVATION FT MSL:  5280                                       USER:  BRADSHAW

             YEARS OF WEATHER DATA REQUESTED:  1950 TO 1977   (18 YEARS)
             SEASONAL DATES OF ANALYSIS     :  MAY  1 TO NOV  1
             TOTAL DAYS AVAILABLE           :   2215 DAYS OVER 16 YEARS

                                    PRESCRIPTION FACTOR SUMMARY

*******************************************************************************************
*                                                                                         *
*    PRESCRIPTION FACTORS                     PREFERABLE CONDITIONS     ACCEPTABLE CONDITIONS  *
*                                               MINIMUM    MAXIMUM       MINIMUM    MAXIMUM   *
*                                               -------    -------       -------    -------   *
*   1.  TEMPERATURE (DEG F)                       65         75            60         80      *
*   2.  RELATIVE HUMIDITY (%)                     20         30            20         55      *
*   3.  WIND SPEED (MPH)                           4          9             0         15      *
*                                                                                         *
*******************************************************************************************

                                  PRESCRIPTION OCCURRENCE SUMMARY

*******************************************************************************************
*                                                                                         *
*                                                    PREFERABLE    ACCEPTABLE    UNACCEPTABLE  *
*                                                                                         *
* DAYS PER SEASON WITHIN PRESCRIPTION                     8            51             80      *
*                             (PERCENT)                   5%           37%            58%     *
*                                                                                         *
* MONTH OF HIGHEST PRESCRITION FREQUENCY                 SEP           JUL            OCT     *
*                 (PERCENT PROBABILITY)                   9%           45%            71%     *
*                                                                                         *
* 10 DAY PERIOD OF HIGHEST RX FREQUENCY BEGINS         JUN  1        JUL  1         MAY  1    *
*                                                      OCT  1                                 *
*                (PERCENT PROBABILITY)                   10%           57%            78%     *
*                                                                                         *
*******************************************************************************************
```

Exhibit 20.--Program RXBURN prescription factor and occurrence summary output for one prescription example.



```
PROGRAM RXBURN:  RUN NO.  1   DISTRICT: FIRELAB              FOREST: MONTANA                      PAGE NO. 2

                              PRESCRIPTION OCCURRENCE BY 10 DAY PERIOD AND MONTH

*******************************************************************************************************
*                                                                                                     *
*        PERIOD              **  PREFERABLE DAYS  **  ACCEPTABLE DAYS  **  UNACCEPTABLE DAYS *
* MONTH  BEGINS  NO. DAYS  MEAN NUMBER PERCENT  MEAN NUMBER PERCENT  MEAN NUMBER PERCENT *
* -----  ------  --- ----  ---- ------ -------  ---- ------ -------  ---- ------ ------- *
*  MAY      1      104       0     5      5%      1     18     17%      5     81     78%   *
*  MAY     11      109       0     5      5%      2     33     30%      4     71     65%   *
*  MAY     21      118       1     8      7%      3     40     34%      4     70     59%   *
*  MAY   TOTAL     331       1    18      5%      6     91     27%     14    222     67%   *
*                                                                                                     *
*******************************************************************************************************
*  JUN      1      110       1    11     10%      3     50     45%      3     49     45%   *
*  JUN     11      109       0     4      4%      2     39     36%      4     66     61%   *
*  JUN     21      106       0     6      6%      3     45     42%      3     55     52%   *
*  JUN   TOTAL     325       1    21      6%      8    134     41%     11    170     52%   *
*                                                                                                     *
*******************************************************************************************************
*  JUL      1      138       0     3      2%      5     78     57%      4     57     41%   *
*  JUL     11      150       1     8      5%      4     62     41%      5     80     53%   *
*  JUL     21      165       0     5      3%      4     63     38%      6     97     59%   *
*  JUL   TOTAL     453       1    16      4%     13    203     45%     15    234     52%   *
*                                                                                                     *
*******************************************************************************************************
*  AUG      1      159       0     7      4%      4     66     42%      5     86     54%   *
*  AUG     11      146       0     3      2%      4     56     38%      5     87     60%   *
*  AUG     21      160       1    10      6%      4     67     42%      5     83     52%   *
*  AUG   TOTAL     465       1    20      4%     12    189     41%     16    256     55%   *
*                                                                                                     *
*******************************************************************************************************
*  SEP      1      137       1    12      9%      3     55     40%      4     70     51%   *
*  SEP     11      129       1    11      9%      3     45     35%      5     73     57%   *
*  SEP     21      117       1    11      9%      2     39     33%      4     67     57%   *
*  SEP   TOTAL     383       2    34      9%      9    139     36%     13    210     55%   *
*                                                                                                     *
*******************************************************************************************************
*  OCT      1       90       1     9     10%      1     20     22%      4     61     68%   *
*  OCT     11       90       0     3      3%      1     21     23%      4     66     73%   *
*  OCT     21       78       0     0      0%      1     22     28%      4     56     72%   *
*  OCT   TOTAL     258       1    12      5%      4     63     24%     11    183     71%   *
*                                                                                                     *
*******************************************************************************************************
*  NOV   TOTAL       0       0     0      0%      0      0      0%      0      0      0%   *
*                                                                                                     *
*******************************************************************************************************
* TOTAL  TOTAL    2215       8   121      5%     51    819     37%     80   1275     58%   *
*                                                                                                     *
*******************************************************************************************************
```

Exhibit 21.--Program RXBURN prescription run length summary output for one prescription example.

```
PROGRAM RXBURN:  RUN NO.  1   DISTRICT: FIRELAB              FOREST: MONTANA                  PAGE NO. 3

                                   PRESCRIPTION RUN LENGTH SUMMARY

*******************************************************************************************
*                                                                                         *
*                   ** PREFERABLE DAY RUNS  ** ACCEPTABLE DAY RUNS  ** UNACCEPTABLE DAY RUNS *
*          PERIOD         * PERCENTILES *          * PERCENTILES *          * PERCENTILES *   *
* MONTH   BEGINS   MEAN  25TH MEDIAN 75TH  MEAN  25TH MEDIAN 75TH  MEAN  25TH MEDIAN 75TH *
* -----   ------   ----  ---- ------ ----  ----  ---- ------ ----  ----  ---- ------ ---- *
*  MAY       1      3     1     1     4     1     1     1     2     4     2     4     7   *
*  MAY      11      1     1     1     1     2     1     2     2     3     1     2     5   *
*  MAY      21      1     1     1     1     2     1     1     2     3     1     2     5   *
*  MAY    TOTAL     1     1     1     1     2     1     1     2     4     1     3     8   *
*                                                                                         *
*******************************************************************************************
*  JUN       1      2     1     1     2     2     1     1     3     2     1     2     3   *
*  JUN      11      1     1     1     1     2     2     2     2     3     1     2     5   *
*  JUN      21      1     1     1     1     2     1     1     2     3     1     2     4   *
*  JUN    TOTAL     1     1     1     1     2     1     2     2     3     1     2     5   *
*                                                                                         *
*******************************************************************************************
*  JUL       1      1     1     1     1     2     1     2     3     2     1     1     2   *
*  JUL      11      1     1     1     1     2     1     1     2     2     1     1     3   *
*  JUL      21      1     1     1     1     2     1     1     2     3     1     2     4   *
*  JUL    TOTAL     1     1     1     1     2     1     1     2     2     1     2     3   *
*                                                                                         *
*******************************************************************************************
*  AUG       1      1     1     1     1     2     1     1     2     2     1     2     3   *
*  AUG      11      1     1     1     1     2     1     1     3     3     1     2     4   *
*  AUG      21      1     1     1     1     2     1     1     2     2     1     2     3   *
*  AUG    TOTAL     1     1     1     1     2     1     1     3     3     1     2     3   *
*                                                                                         *
*******************************************************************************************
*  SEP       1      1     1     1     1     2     1     1     2     2     1     2     2   *
*  SEP      11      1     1     1     1     2     1     2     3     3     1     2     5   *
*  SEP      21      1     1     1     1     2     1     1     2     3     1     2     3   *
*  SEP    TOTAL     1     1     1     1     2     1     1     2     3     1     2     4   *
*                                                                                         *
*******************************************************************************************
*  OCT       1      1     1     1     1     1     1     1     2     3     1     2     4   *
*  OCT      11      2     1     1     2     2     1     1     3     4     2     3     6   *
*  OCT      21      0     0     0     0     2     1     1     2     2     1     1     2   *
*  OCT    TOTAL     1     1     1     1     2     1     1     2     4     1     2     5   *
*                                                                                         *
*******************************************************************************************
*  NOV    TOTAL     0     0     0     0     0     0     0     0     0     0     0     0   *
*                                                                                         *
*******************************************************************************************
```

Exhibit 22.--Program RXBURN prescription occurrence by 10-day period and month output for one prescription example.

```
PROGRAM RXBURN:  RUN NO.  1    DISTRICT: FIRELAB                FOREST: MONTANA                PAGE NO. 4

         PROBABILITY OF MEETING PRESCRIPTION 1, 2, AND 3 DAYS IN THE FUTURE

************************************************************************************
*                                                                                  *
*                                MONTH:   MAY                                      *
*                                                                                  *
*     TODAYS   *** TOMORROW ***    **** 2 DAYS ****    **** 3 DAYS ****       N DAYS  *
*      COND    PREF  ACCP  UNAC    PREF  ACCP  UNAC    PREF  ACCP  UNAC               *
*                                                                                  *
*      PREF     17%   50%   33%      9%   38%   53%      7%   32%   61%   PREF    18  *
*                                                                                  *
*      ACCP     12%   47%   41%      8%   35%   55%      7%   31%   62%   ACCP    85  *
*                                                                                  *
*      UNAC      2%   18%   80%      4%   24%   72%      5%   25%   68%   UNAC   216  *
*                                                                                  *
************************************************************************************

************************************************************************************
*                                                                                  *
*                                MONTH:   JUN                                      *
*                                                                                  *
*     TODAYS   *** TOMORROW ***    **** 2 DAYS ****    **** 3 DAYS ****       N DAYS  *
*      COND    PREF  ACCP  UNAC    PREF  ACCP  UNAC    PREF  ACCP  UNAC               *
*                                                                                  *
*      PREF     20%   60%   20%     10%   51%   39%      8%   45%   47%   PREF    20  *
*                                                                                  *
*      ACCP      9%   56%   35%      8%   47%   45%      7%   43%   49%   ACCP   132  *
*                                                                                  *
*      UNAC      3%   28%   69%      5%   37%   58%      6%   40%   54%   UNAC   173  *
*                                                                                  *
************************************************************************************

************************************************************************************
*                                                                                  *
*                                MONTH:   JUL                                      *
*                                                                                  *
*     TODAYS   *** TOMORROW ***    **** 2 DAYS ****    **** 3 DAYS ****       N DAYS  *
*      COND    PREF  ACCP  UNAC    PREF  ACCP  UNAC    PREF  ACCP  UNAC               *
*                                                                                  *
*      PREF      0%   75%   25%      4%   48%   48%      4%   45%   51%   PREF    15  *
*                                                                                  *
*      ACCP      4%   52%   44%      4%   46%   51%      4%   45%   52%   ACCP   205  *
*                                                                                  *
*      UNAC      3%   36%   61%      3%   43%   54%      4%   44%   52%   UNAC   227  *
*                                                                                  *
************************************************************************************
```

Exhibit 23.--Program RXBURN probability of meeting prescription in the future output for one prescription example.

This option has one restriction: parameters not computed in the first directive block will not be available for analysis in subsequent blocks. This applies only to National Fire Danger Rating System (NFDRS) indices, fuel moisture values, and duff moisture computations. Fuel moisture is computed if either fuel moisture or an NFDRS index is requested. NFDRS indices and duff moisture are computed only when requested. NFDRS fuel models and site adjustments cannot, therefore, be altered after the initial directive block. The following example shows how to analyze four prescriptions at the same station. The site adjustment option is used in this example.

Example of Multiple Prescription Analysis

```
            card columns

                      1         2         3         4         5         6         7   8
            01234567890123456789012345678901234567890123456789012345678901234567890...0


            @RUN

            @ASG,A WEATHER.

            @USE 15.,WEATHER.

            @ASG,T 2.

            @ASG,A CSSG*R1LIB.

            @XQT CSSG*R1LIB.RXBURN
----------
            01

            STATION

              ANY STATION      123456  2345 45 H 3 P 3 0615  T T  2  4500. 1
first
            YEARS     1900  1978

            DATES     0101  1215

            ACTIVITY

directive       DEMONSTRATION OF MULTIPLE PRESCRIPTION ANALYSIS

            IDENTIFY

            LARRY BRADSHAW         FIRE LAB           MISSOULA

            PRESCRIBE 01
block
                 NFDRS  ERC                    2    4    1  10

            RUN
----------
```

```
         01

        ,STATION
econd   {
          SAME STATION  123456  2345  45 H 3 P 3 0615 T  T 2 4500. 1
        
        YEARS     1900  1978
irective{
        DATES     0101  1215

        PRESCRIBE 01
lock    {
             NFDRS ERC               4    8    4    15

             RUN
─────────

         01
hird
        PRESCRIBE 01
irective{
             WIND SPEED             13   18   10    20
lock
             RUN
─────────

         01

        PRESCRIBE 03
ourth   {
             WIND DIRECTION          D    W    S    NW
irective{
             WIND SPEED              4    8    2    12
lock    {
             MAX TEMPERATURE        65   72   60    78

        RUN
─────────

        @EOF

        @FIN
```

Error Messages

1 No recognizable input cards - Incorrect input stream - Program Aborted.

Cause: Misspelled control word on a control card, or control card word not beginning in column 1.

2 At least one option is incorrect or was started in the wrong column - Program Aborted.

Cause: Misspelled option after the PRESCRIBE control card, or option card did not begin in column 6.

5 Difference between site and AFFIRMS station greater than 2000 feet, no adjustments made.

Cause: Self-explanatory.

Output Quantities

For each station and/or prescription analysis in a single RXBURN run, approximately five pages of output are produced, with a maximum of nine for a full 12-month analysis.

Cost Estimates

For a typical RXBURN run (one station, 5- to 6-month analysis, three to four prescription parameters) a user can expect costs and resource use as outlined below.

Run priority	Cost	CAU (sec)	Resource time
DEMAND	$4.00 to $5.00	8 to 9	10 to 11
L	$2.00 to $2.50	8 to 9	10 to 11
N	$1.00 to $1.50	8 to 9	10 to 11
P	$0.75 to $1.00	8 to 9	10 to 11

PUBLICATIONS CITED

Bradshaw, Larry S., and William C. Fischer.
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☆ U.S. GOVERNMENT PRINTING OFFICE: 1980—777-028/168 Region No. 8

Bradshaw, Larry S., and William C. Fischer.
1981. A computer system for scheduling fire use. Part II: computer terminal operator's manual. USDA For. Serv. Gen. Tech. Rep. INT-100, 34 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Provides program writeups, including input requirements, keypunch instructions, job control language, example of output, error messages, and cost estimates for two computer programs: RXWTHR and RXBURN. These programs comprise a system designed to aid in predicting the probable occurrence of desired prescribed fire weather conditions.

KEYWORDS: prescribed fire, fire use plans, climatology, computer programs.

Bradshaw, Larry S., and William C. Fischer.
1981. A computer system for scheduling fire use. Part II: computer terminal operator's manual. USDA For. Serv. Gen. Tech. Rep. INT-100, 34 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

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The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

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Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)